POWER DEVELOPMENT OF SMALL STREAMS

CARL C. HARRIS
SAMUEL O. RICE

For men may come and men may go,
But I go on forever.
—The Brook, by Alfred Tennyson.

POWER DEVELOPMENT OF SMALL STREAMS

A Book for All Persons Seeking Greater Comfort and Higher Efficiency in Country Homes, Towns and Villages.

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Introduction

The purpose of this book is to furnish the layman in an accurate and simple way, a practical and working knowledge of installing and operating small water power plants for furnishing country homes, towns, and villages with electric light, power, heat, water supply, and fire protection. Technical language has throughout been eliminated or made so plain there can be no confusion to any reader. Too long has the knowledge necessary for the developing of the thousands of country home, town and village water power opportunities been buried in the technicalities of engineering works or to be obtained only by the expensive process of employing an engineer who is an expert on water power development. This book removes that hindrance to the country home, the town or village obtaining greater comfort, efficiency and almost all the modern conveniences now denied them. The possibilities of power development on small streams are practically unlimited. There are no legal tangles or governmental restrictions that face many large power projects. The small power plant is the cheapest source possible for the country home, town or village to obtain electricity, power, heat, and water supply. The small power plant is well within the reach of the average country dweller, or the town or village. Water power development has reached the stage where there is a water wheel for every stream from the tiniest rivulet to the great river.

The authors are indebted to La Hacienda, Buffalo, N. Y., The Mayhew Company, Milwaukee, Wis., Alpha Cement Company, Easton, Pa., the Scientific American, New York, N. Y. and the United States Reclamation Service, for their courtesy in loaning drawings and supplying valuable information which has helped make the book more complete and useful.

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Power Development of Small Streams

CHAPTER I

The Willingness of Water to Work

FOUR men with milk pails dipping water from a tank and pouring it into a garden furrow would form only a tiny rivulet. Yet if they poured the same quantity of water into a downspout eleven feet long they would generate one horse power of energy, providing there was a water wheel at the bottom end of the downspout to catch and transform the force of the falling water into electricity or other mechanical energy. One horse power alone has enough energy to furnish electric current for eighteen 40-watt or thirty-six 20-watt lights and therewith to light two average country homes, barns, barnyards and outbuildings complete, besides providing heat for ironing and power for such small work as washing, churning, sewing, and electric fans. And one horse power can be produced by seven and one-half gallons of water falling eleven feet a second to a water wheel or turbine.

This homely illustration, four men "sloshing" water out of a tank with milk pails to provide water power to operate eighteen large or thirty-six smaller electric lights, or to furnish heat and power, pictures sharply and accurately the wonderful willingness of water to work. Water power is the greatest undeveloped natural resource in America today. The United States Geological Survey estimates that thirty million horse power is going to waste in the streams that have not been put to work. The "Journal of Electricity", No. 1, Volume 41, says a maximum of fifty-four million horse power and a minimum of twenty-eight million horse power still await possible development in the streams of the Nation. Beyond doubt power development of small streams is the most democratic of all our natural resources. It is the one greatest natural resource available to the largest number of Americans, since thousands of farms, towns, and villages with

brooks, creeks, rivers, and spring branches have this cheapest of power ever ready at hand. Few farm streams but are capable of being harnessed practically and cheaply, at least to pump water, or to do more than that, to furnish light, heat, and power for a single farm or a country home, or for a group of homes or an entire village or town.

There is one horse power to be had from the milk-pail rivulet. There are three, four, five, ten, twenty, possibly greater horse power to be had from the farm brook that a man can step across. There is enough power running to waste in the shallow, rippling creek, spanned by a footlog, easily to take the drudgery out of a half dozen country homes that still use kerosene lamps and employ tired muscles to carry water and to other work that should be done by machinery. That same little stream is the most practical and cheapest chance for the village's best development—by installing a small water power plant to furnish electricity and fire protection for the community. Truly the willingness of water to work is a wonderful thing. Water in motion is exactly equal to water under pressure, and the brook, spring branch or creek will run down a flume or pipe and operate the machinery of a home power plant and machine shop just as readily as it will splatter down a riffle or tumble over a boulder. All it wants is a chance to work.

CHAPTER II

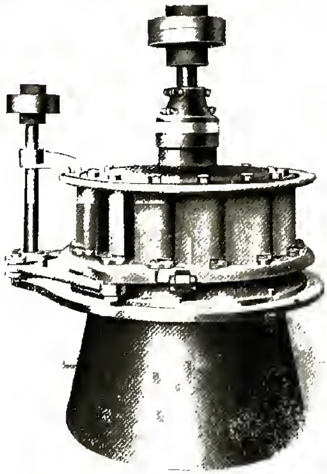
How a Country Home Got a Water Power Plant

BURNING of a country church in a fire caused by a kerosene lamp led to the installing of a farm water power plant that is typical in experience and in practical results. It is a guidepost to any man or woman who lives in a country place that has a brook, spring branch or creek, or who lives in a small town or village near a small stream. The congregation, in a meeting in the district school to apportion the assessments for building a larger and better church, was discussing lighting systems, when a farmer named Rowlands made the epochmaking talk, hardly a speech, of that neighborhood. Mr. Rowlands lives about a mile across fields from the church.

"As a member of the building committee," said Mr. Rowlands, "I have been entrusted with the lighting question. As some of you know, I've been figuring on putting in at my home"— He mentioned a very excellent gas lighting system, one that is approved by the National Board of Fire Underwriters.

"It would cost me," he continued, "about $300 to pipe my house, put in shades and fixtures and a complete gas lighting plant. It would cost the church about the same sum. Now you've got me down for $300 on the new church. You'll spend my $300 for a lighting plant. Well, I've been figuring further. I don't want to make a cent off the church, but if you will cancel my assessment I can put in a little water power plant on the creek on my farm and I'll guarantee to furnish enough electricity to light both the church and the school. It will cost you about $15 or $20 to run a church lighting plant. My way it won't cost the church a cent and it will cut down the fire hazard and the insurance rate on both the church and the school. If I fall down I'll agree to put in the gas lighting system for the church at my own expense. I'll put this in writing, if you like."

It would be nice to write how Brother Rowlands's plan fulfilled all expectations in lighting the church. But it did not do it.



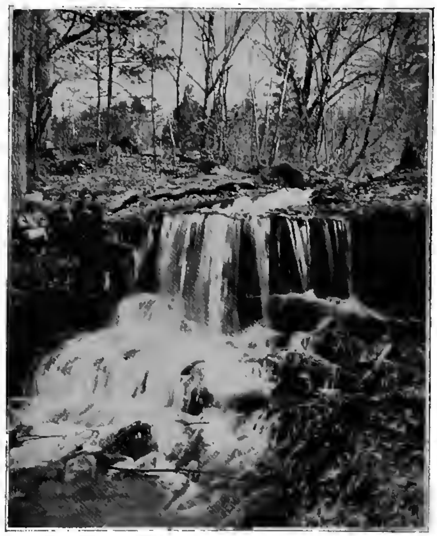
A Type of Turbine Water Wheel, Simple and Almost Everlasting

It was a half-way failure at first. The plant was in operation and furnishing electric light, power and heat at the Rowlands home with entire satisfaction several months before the church was finished. But when the church lights were turned on they were decidedly dim and inadequate. For several weeks almost the whole congregation searched for the cause of the trouble. Then Mr. Rowlands complained to the manufacturer of his electric generator. The manufacturer replied in a letter asking a half-dozen questions. When those questions were answered, he smiled and wrote:

"My dear Mr. Rowlands: Why did you not tell us you wanted to carry current across country two miles. The trouble is in the size of wire from your plant to the church. It is too small. In the back part of the booklet we sent you is a table of wire sizes for varying currents and distances."

Then he gave specific directions for taking down and selling the old line and replacing it with larger wire. He suggested minor changes, the correcting of a faulty point or two in insulation. After that the lights burned brightly in the church and the school and there was no more trouble, except one night a future electrical engineer of fourteen years poked a pin through the cord of a drop light, short-circuited the system and blew out a fuse. The church supper was in darkness almost five minutes, until the first automobile owner who could find a match, replaced the fuse. The small boy was not hurt. Electric current from these small plants is in nowise dangerous.

The foregoing incident took place in the first half of 1914. The war probably has changed somewhat even the approximate figures of costs given here from Mr. Rowlands's experiences. When Mr. Rowlands first began work on his plant he figured he needed about five horse power to do the farm's work and furnish light and also heat for ironing. He could easily get a head of fifteen feet on his brook, "head" meaning the distance the water would fall from the intake of the mill race, pipe or flume to the wheel itself. Fifteen feet fall with a little turbine wheel only nine inches in diameter would give him 5.72 horse power with one type of turbine wheel called a New Pattern Hunt Francis Cylinder Gate Turbine, while another type, called Hunt McCormick, would develop eight horse power. While the Hunt McCormick type of turbine of the same size as the Hunt Francis type developed approximately a third more power under the same head, or fall of water, the McCormick wheel required quite a bit more water than the Hunt turbine. So Mr. Rowlands, having but a small brook, decided that he would use Hunt type. By referring to his catalogue he saw that the next size turbine wheel of the type he had selected, a 12-inch wheel, would develop 8.52 horse power under a 15-foot head, while the next larger size, a 15-inch wheel, would give 17.17 horse power under that head and an 18-inch wheel would develop 26.81 horse power. Turbine wheels are three inches larger in each successive size up to sixty inches. From the 60-inch wheel they are six inches larger in



THE BROOK—AS POWERFUL AS NIAGARA FOR THE HOME NEEDS

diameter for each successive size wheel, up to the 96-inch turbine wheel, which Mr. Rowlands saw would develop 995 horse power under a 15-foot head, but would require vastly more water than this brook held in its worst flood.

The whole Rowlands family became interested in that little turbine wheel book. It was fun speculating on what they could do with a larger wheel or by lengthening the distance the water fell to the wheel. Under a 20-foot head, they found, the 9-inch turbine wheel would develop 8.90 horse power, the 12-inch wheel would produce 13.24 horse power and the 15-inch wheel, 26.70 horse power. The 18-inch turbine wheel develops 41.16 horse power under a 20-foot head and the 21-inch wheel, 57.82 horse power under the same head. Mr. Rowlands, however, said he was going to start small and if the thing worked all right some day he'd sell the little wheel and put in a larger one.

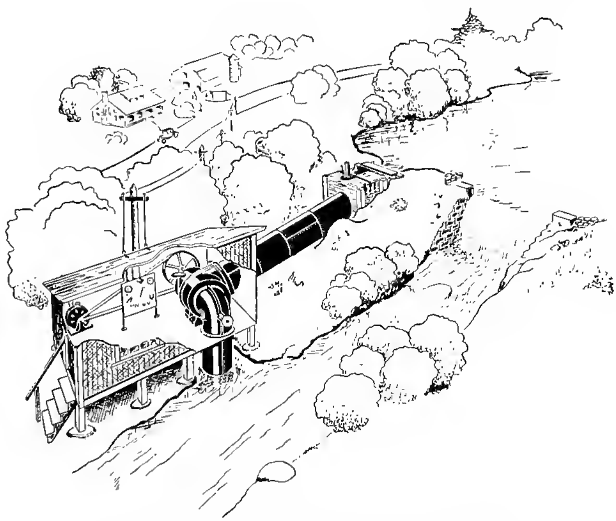
The Rowlands place is a 210-acre farm stretching across a small valley onto low, gently sloping hills on either side. The farm stream is, in New England, a brook, west of the Alleghenys, a creek. At its narrow points a high school boy can leap it in a running jump. It is not a very swift stream, just the ordinary, rapid-flowing brook or creek of ten thousand farms, with stretches of rapids or riffles between deeper, quieter pools here and there. Mr. Rowlands built a dam four feet high at the head of the riffle with the longest fall. The dam was placed at a point where the brook changes its course from along the bottom of the hill and turns out into the valley, only to turn back to the hill a little farther down. Mr. Rowlands dug a ditch five feet wide and three feet deep, much too large, he now admits, but you must remember that he was the pioneer in water power development in his community. He was banking on the word of a distant turbine wheel manufacturer that after all he might not have to go to the extra expense of installing a $300 gas lighting system in the church to make his own word good. Besides, the ditch cost nothing but the labor at a time when there wasn't much else to do on the farm, and a big part of the work was done by plowing and "slipping" the earth and small stone out on the down-hill side with a hand scraper.

The ditch or small mill race led straight along the bottom of the hill about two hundred and fifty feet to a point where there was a steep decline, probably formed when the stream bent a new course at that point years and years ago. Here Mr. Rowlands had the 15-foot fall he wanted. The bottom of his little mill race sloped very gently to the edge of this decline or bank, at the bottom of which Mr. Rowlands put in a rough dry foundation of stones, open at one side, and on which he built an odd-looking structure. It was much like a little, square silo might be. It was 5 feet by 5 feet, inside dimensions, and was made of cheap, rough boards an inch thick, 6 inches wide and 5 and 6 feet long, laid flat on top of one another and spiked tightly together. The walls of this elongated box set at the base of the bank were thus solid and six inches thick. The box itself was a little more than fifteen feet tall.

Mr. Rowlands connected the top of this box with the lower end of his mill race by building a rough wooden trough or flume 8 feet long, 5 feet wide, and 3 feet deep. The water was to run down the mill race, through the trough or flume, into the box. In the floor of the box Mr. Rowlands made a circular opening in which he set the little 9-inch turbine wheel. On the top of the box he built a shed, a little larger than a small garage and extending from the box out onto the bank. The power or driving shaft of the turbine wheel ran straight up from the wheel, through the floor of the shed and transmitted its energy through a crown gear to a line shaft, which in turn was belted to an 800-watt, direct current electric generator and to a feed mill, a circular saw, an emery wheel, a grindstone, and a pump. A gate control, for starting, stopping, and regulating the speed of the turbine wheel, and a switchboard and storage batteries completed the equipment of the power house.

At the head of his mill race Mr. Rowlands put in a trash rack to keep leaves and floating debris out of the race, and a wooden gate to shut the water out if desired. Below the power house he plowed a deep, double furrow to the brook farther down, to give the discharge from the turbine wheel a direct and easy course to the stream. Much of the plant was overlarge and clumsy, but it has proved entirely efficient and dependable ever since the first

day it was put into use, excepting the one avoidable incident of using the wrong size wire for the transmission line to the church. The only additions that have been made to the plant have been a second trash rack, at the lower end of the mill race, and a small electric motor at the house to operate a washing machine. The plant was constructed and put into successful operation entirely



A Home Electric Light and Power Plant Operated by a Turbine Water Wheel

by men with no experience in water power development. Besides giving all the electricity for light needed at the Rowlands home, furnishing power for pumping, sawing wood, heat for ironing, and running practically all the stationary machinery of the farm, except an ensilage cutter, the Rowlands water power and electric plant has proved a neighborhood benefit in lighting church and school. Mr. Rowlands realizes now that he might have done much better by installing a larger wheel. Or it could have been a much easier and neater job by running a small wood pipe from the dam to a horizontally-mounted turbine wheel and set in a corner of the power house. Such an arrangement would have eliminated the big, clumsy wheel pit Mr. Rowlands built and the slightly less efficient vertically mounted turbine wheel that of necessity must

lose a small fraction of its power through the crown gear. A more desirable home power plant for the Rowlands farm would have been more like the home plant pictured above, consisting of a somewhat larger wheel, a much shorter flow of water and lower head or fall through a steel plate pipe to a 60-dollar shed in which is placed a horizontally mounted turbine wheel, an electric generator and switchboard. As shown in the picture, the electric current generated by this plant is carried on a line to the home and barn, in the background, where it is used in providing light, heat, and power.

CHAPTER III

A Wheel for Every Stream

WATER turbine wheels are 80 to 90 per cent efficient, with some reliable tests showing even higher efficiency than 90 per cent. That assertion may not make a strong appeal to the average man or woman, but lay it alongside the cold, hard fact that it takes the very highest type of gasoline or internal combustion engine to reach as high as 40 per cent efficiency, that the average steam plant operates around 15 per cent efficiency, with many steam plants showing only 10 per cent efficiency and with only an occasional few reaching the maximum—for steam—of 25 to 35 per cent efficiency. Electric generators and motors run as high as 95 per cent efficient in operation, but since they must depend primarily upon steam, gas or water for power, their efficiency in any kind of plant is affected by the kind of driving power employed.

This comparison of power-developing machinery indicates sharply the opportunities to profit by harnessing the country home's brook for light, power, heat, and water works, or, by installing a turbine water wheel at the end of the long riffle where the town boys go swimming in summer, to give electricity and fire protection to the town.

It will cost about $160 and up for each horse power harnessed by a water power plant. That is a minimum figure, not the average. Quite possibly the average on many farms would be about $320, possibly more, possibly less. No two plants cost the same. But whatever the figure, it will not cost as much to harness water horse power as to put and keep leather harness on each horse power in actual horse flesh on the farm. For this water power harness does its work tirelessly and continuously on horse power that never tires, never gets sick and requires neither oats, hay, bedding nor curry comb. Its repairs are less than horseshoeing bills. Its "feed," or "fuel," costs nothing, since the brook or

creek furnishes a steady, unending supply of "white coal," as the thrifty Swiss with their extensively developed hydro-electric plants call water power. Even the somewhat primitive water power plant on the Rowlands Farm, described in the previous chapter, the little water wheel, buried in water, never freezes, never heats up. It doesn't even need oiling and it costs nothing to run it.

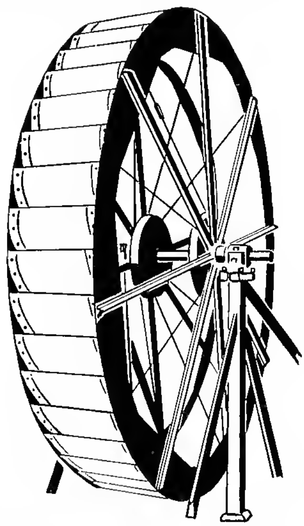
Harnessing a brook not only is much cheaper than harnessing steam, gasoline, kerosene or living horses, it is cheaper than buying electricity from transmission lines that pass farms here and there, carrying electric current from town to town or from a large power plant to the city. The minute a country dweller taps such a transmission line his monthly bills for current begin. They never cease so long as he uses current. In addition he pays the cost of installing a transformer, a meter, and a private line, which will amount to $200 or more. It is infinitely cheaper for the dweller near a small stream to put in his own plant. That fact is so apparent with a little looking into this subject of water power, that big, successful business men with the best engineering advice money can buy, have spent the huge sums of $300 and $400 a horse power and more in developing great industrial and commercial water power plants. The first cost is practically the whole cost and after that the plant operates for years for almost nothing. The power that runs it is free. Only the harness costs.

In estimating the cost of electrical generators, switchboards, storage batteries and wiring for a home power plant, about $225 a horse power, or 746 watts, is a fair figure. For a village or small town plant $160 a kilowatt is a generous figure for the plant's electrical equipment alone. A kilowatt is a unit of electrical power that is equivalent to 1.34 horse power. It is sufficient to furnish current for twenty-five 40-watt lights or for fifty 20-watt lights or to do the work that 1.34 horse power would do in a water wheel, steam or gas engine.

But some man or woman with an investigating mind, like Mr. Rowlands, may say that turbine water wheels are all very well for country homes with brooks or creeks, but where only a tiny spring branch, a mere rivulet, is available, water power is out of the question. That is a mistaken notion. There is a practical

water wheel for every stream. If the rivulet flows as much as six gallons of water a minute, in the dry period of the year for that locality and a stream less than a foot wide and only an inch or two deep will do that, it will operate a water wheel pumping plant and pump 360 gallons of water a day practically any distance and to a height of 100 feet. If the rivulet flows 50 gallons a minute, the home water wheel pumping plant will pump 2,500 gallons of water a day, practically any distance and to a height of 100 feet, pumping not the perhaps impure water that operates the wheel, but pure water from another stream, spring or pond.

The great beauty of water power development is that there is a wheel for every stream. These wheels are divided roughly into two classes, impulse and reaction wheels. The reaction wheel is the turbine, the water motor to be used, as in Mr. Rowlands's case, where five horse power and up are to be developed. The impulse wheel, a drawing of which is shown on this page, is a highly modern descendant of the old overshot water wheels that have been used for hundreds of years. Today they are called rim-leverage wheels, not overshot wheels and with the losing of the old name they have lost, too, the clumsiness and wasteful inefficiency that characterized the old overshot mill wheels. They are intensely efficient machines, compact, durable and beyond doubt the cheapest power-developing machine in the world today. The paddles, or buckets, are shaped and set with mathematical accuracy so that the wheel absorbs almost the entire energy of the falling water and each drop of water is caught and held by the wheel just so long as it has power to impart and then is dropped into the tail race without having had a fraction of a second's free ride on the wheel.



A Rim-Leverage Water Wheel, the Cheapest Practical Power Developing Machine yet Devised

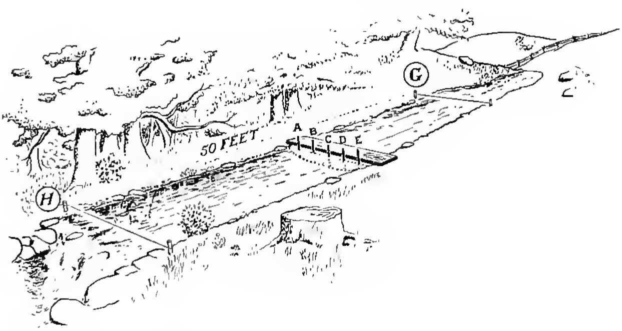
Rim-leverage wheels are made of wood or of steel, to suit different pocketbooks. They may be mounted on the side of a stream without being sheltered. The water is conveyed to them by a trough or pipe and imparts its force by falling directly onto the wheel. In smaller sizes rim-leverage wheels are used with pump combination only, to supply the home water works system. In the larger sizes, developing several horse power, rim-leverage wheels are used to drive electric generators and to do other small work besides pumping water and furnishing electric current for light, heat, and small power work. Chapter VII, page 49, takes up in further detail the rim-leverage wheel.

For each possible power site on a spring branch, brook, creek or river there is a rim-leverage wheel or a turbine wheel that is cheapest and best for the fullest economic development of that plant, whether it is only a little home pumping plant, a home power and electric plant, or a larger installation to supply village, town, city or factory. But before we follow that interesting path explored by Mr. Rowlands, the chances for using water wheels in the home stream, before we look further into the nature of that very simple mechanism, the turbine water wheel, let us take a look at any small stream anywhere to see if we cannot determine accurately what practical usefulness may be got out of it. Turbine wheels are described in full and illustrated in Chapter VI, page 41.

CHAPTER IV

Invoicing a Small Stream

THE strangeness of the problem doubtless is the one thing that has caused practically every man and woman owning a small stream power site to neglect investigating the practicability of using the stream for power, light, heat, and pumping water. Where can one begin to solve such a problem? It seems formidable because it is strange. But let us walk down to any small stream on any farm or near any town, anywhere, and find out



Showing a Brook Ready to be Invoiced by Using a Plank, Seven Stakes, Five Chips, and the Multiplication Table

quickly and accurately just what that stream is worth. What unused good has that brook or river in it for me, my home or my town?

Here is a fairly even stretch of the stream, as is pictured in the drawing on this page. Just above a little riffle, shown at the left of the picture, we drive a stake, H, and measure fifty feet directly upstream where we drive a stake, G. Now we drop a wooden block or chip about two inches square in the stream at G and time it as it floats that measured fifty feet to H. We drop a second block or chip and time it as it floats from G to H. One

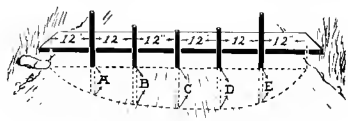
after the other we drop three more chips and time them as they float the measured fifty feet from G to H. The first chip floats fifty feet from G to H in 10 seconds. The second chip floats the same distance in 8 seconds. The third chip requires 11 seconds to make the distance; the fourth chip, 9 seconds, and the fifth chip, 12 seconds. We are trying to learn how fast the brook flows in this 50-foot stretch we have measured off. So to get the average time of the five chips we add together the time made by each of them which equals 50. We divide 50 by 5, the number of chips, which gives us 10, therefore 10 seconds is the average time of the chips in floating that fifty feet, or 5 feet a second, 10 into 50 is 5.

But no stream flows evenly throughout its width. It is slower near the banks and bottom because there is friction between the water and the bottom and banks. The flow is swifter in the center just below the surface, where there is least friction. Consequently five feet a second, the average time of the five chips is too fast, so we deduct 20 per cent from this average speed or velocity by multiplying 5 by .80, which gives us 4 feet a second as the mean velocity of the stream in this 50-foot stretch. There we have the answer to one of the three simple questions we must answer to learn how much power is running to waste in the stream. We have found how fast the stream flows in a certain length or stretch and it does not make any difference where we measure off that stretch of the stream, the ultimate results will be the same.

Next we want to learn how much water is flowing down that 50-foot stretch, or in any other sector of the stream we have decided to use in invoicing the stream's possibilities. After that we will have to determine how much drop or fall we can get, since the farther the water falls from the dam to the wheel the greater the power developed. When we have answered these remaining two questions we will know all that is necessary to know about this stream in deciding how it can best be put to use.

To find out how much water is flowing in the stream, we lay a plank across the stream midway between stakes G and H, as shown in the drawing on page 26. Standing on this plank we drive the stake A, which is just a foot from the bank on the left-hand side of the brook, as shown in the drawing on page 26, but

given in a larger cross-section view lower down on this page. A foot farther out from stake A we drive stake B, and a foot farther still we drive stake C, then stakes D and E, at 1-foot intervals, indicated in the drawing on this page. The brook is only six feet wide. If it were wider, we would drive more stakes at 1-foot intervals. The plank is included merely as a convenience and may be omitted. Now we measure the depth of water at each stake.



CROSS SECTION OF STREAM

We find that it is 9 inches deep at stake A; 11 inches deep at stake B; 13 inches deep at stake C; 15 inches deep at stake D and 12 inches deep at stake E. To get the average depth we add together the depth of all five stakes, which gives us 60 inches, and divide by 5, which gives 12 inches as the average depth of that particular width of stream. This may seem rather simple arithmetic, but its purpose will all be clear in the next few lines.

Suppose the plank laid across the stream is a foot wide, then that part of the brook immediately beneath the plank would be a section of the stream the width of the plank, 1 foot, the length of the plank, 6 feet, and with an average depth of 1 foot. In other words, the part of the stream immediately beneath the plank would be a slice of the brook, 1 foot wide from the upstream edge of the plank to the downstream edge of the plank, 6 feet from bank to bank, and with an average depth of 1 foot. Well, how much water, what quantity of water, is in such a slice of the stream? We want the answer in cubic feet, so we multiply together those three dimensions of the slice of brook, 1 x 6 x 1 equals 6, or 6 cubic feet, the quantity of water in the slice of brook we so carefully measured. A cubic foot of water is 7½ gallons, so we have 45 gallons of water in that slice of brook, to express it in the more usual unit of measure. We have already determined that the brook flows 4 feet a second. That slice of brook we have measured flows just as fast as any of the rest of the water passing that point, so to get the rate of flow we multiply the speed, 4 feet

a second, by the quantity of water, 6 cubic feet, and find that the stream flows 24 cubic feet of water a second. At that rate it flows 1,440 cubic feet of water a minute, since there are 60 seconds in a minute and 60 multiplied by 24 equals 1,440. There we have the answer to the second question, how much water does the stream flow?

A horse power is 33,000 pounds dropping one foot in one minute. Thus, 33,000 pounds of water falling one foot in one minute will develop one horse power. Now we have 1,440 cubic feet of water a minute in the stream we are invoicing. Each cubic foot of water weighs 62½ pounds, so the total weight of the water flowing down this stream each minute is equal to 1,440 cubic feet multiplied by 62½, which is 90,000 pounds. If we drop 90,000 pounds of water one foot in one minute, how much horse power would the stream develop? Dividing 90,000 by 33,000, the result is 2.72 horse power.

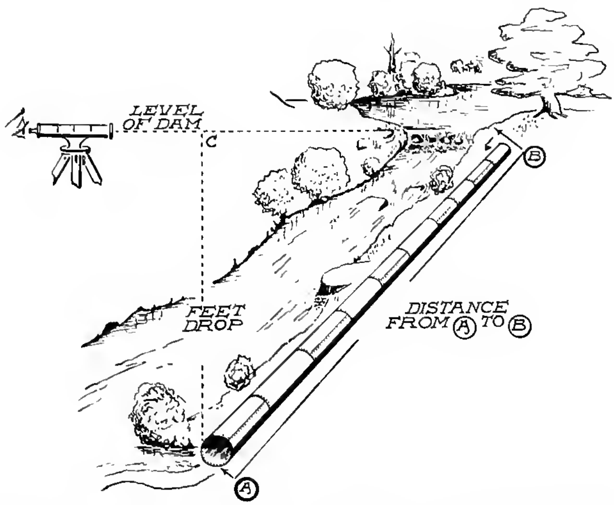
However, we must remember that developing power under such low heads as one foot, or even two or three feet, is not the cheapest or the most practical method in small streams. It is better for us to have a 15-foot head, or fall, as Mr. Rowlands did. With a 15-foot head we saw that Mr. Rowlands's little 9-inch turbine wheel developed 5.72 horse power, and required only 246 cubic feet or 17,365 pounds of water a minute to do it. In fact, 246 cubic feet of water was all the water that particular type and size of wheel could use under a 15-foot head. No matter if the whole Mississippi River were surging about it, only 246 cubic feet of water would go through that wheel under a 15-foot fall. To get more power out of that size and type wheel the head or fall of the water must be increased, thus increasing the quantity of water the wheel could use. It is impossible to strain or to damage a water wheel by overloading. It can and will do just so much work, right up to its big 80 to 90 per cent efficiency, and there it stops. It is the mule of the entire world of machinery. If we propose to use all the 1,440 cubic feet of water a minute that flows in the stream we are invoicing we will have to employ a larger type of wheel than the one Mr. Rowlands uses. Even under 100-foot head his turbine wheel would use only 634 cubic feet of water a minute, but it would develop 99.60 horse power. We

would still have half of the water going to waste in using that type of 9-inch wheel, even if we cared to or were situated to install the heavier pipe or penstock construction to handle a fall or head of water of 100 feet.

Obviously if we want to use all the 1,440 cubic feet of water a minute in the brook, we must get a larger wheel. A 21-inch turbine wheel would use 1,435 cubic feet of water a minute under only a 12-foot head and would develop 26.74 horse power. That figure applies only to the New Pattern Hunt Francis Cylinder Gate Turbine Wheels. The same size Cylinder Gate Hunt McCormick Turbine Wheel would develop 32.9 horse power under a 12-foot head, but it would require 1,815 cubic feet of water a minute, which is more water than our "sample" stream averages. Or, a 24-inch Hunt Francis cylinder gate type would use 1,406 cubic feet of water a minute under only a 7-foot fall and would give 15.28 horse power in return, while the 24-inch Hunt McCormick cylinder gate type would use 1,831 cubic feet of water a minute under a 7-foot head and develop 19.4 horse power. The situation then, is that where there is a large quantity of water and a low fall available, there must be a larger wheel, or better, a pair or series of turbine wheels, to develop the water power plant fully. The stream to be utilized may be deep, or wide and flow slowly, through a flat country and it might be utterly impracticable to obtain even a 15-foot head of water within a reasonable distance. In such case a low head of water must be used and the type and size of turbine wheel that fits best in that particular development. There is a size and type of turbine wheel to fit any combination of quantity of water and fall of water to the very best advantage and fullest development of the plant under those specific conditions.

When a stream is very rapid or it is feasible to get a considerable drop or fall of water in a short distance, the development points to the use of a smaller size wheel. Perhaps the stream is only a tiny brook and hasn't enough water to run a large turbine wheel. Then, the thing to do is to let the small volume of water fall a greater distance to a small turbine water wheel and in that way develop as much power as the larger wheel that operates under a lower head, but with a greater volume of water. It seems that Nature has provided every aid for harnessing water power.

In the mountains and hills the streams may be small and rapid, affording only small volumes of water, but high heads are easily available and thereby the little streams are capable of developing much power. Out on the plains and in the broader valleys the larger streams flow slowly but they afford a large volume of water to make up for the lack of head. On pages 140 to 152 of this book



The Dotted Line, C to A, Illustrates the Common Term, "Head of Water," Available to Operate the Water Wheel

you will find different types and sizes of turbine water wheels rated, showing the power development of each type and size under different heads of water, the quantity of water required and the number of revolutions a minute of the wheel.

We have now come to the last of the three questions we had to answer in taking stock of our sample stream: What head or fall can we have? The picture on this page indicates what is meant by head, fall, or drop. It is the distance on the dotted line from C to A. It does not matter much what the distance is that the water flows through the pipe from an inlet B near the dam to A, where the turbine wheel would be placed, so long as that distance is not so great as to make cost of laying pipe, building flume or mill race prohibitive. We are concerned chiefly with how much vertical drop we can get, as indicated by the line C to A.

Well, I can guess a grade or drop of a stream pretty well, one man boasts.

Possibly he can, but the chances are 500 to 1 that he cannot. If ever you have seen young engineering students guessing at grades you will appreciate the truth of that. Let's not guess. We want everything in this procedure to be absolutely dependable. Nor need we call a surveyor out from town. That would cost money. Let us employ the simple tools and methods that Mr. Rowlands used, a 10-foot straight-edge, such as stone masons use, a carpenter's spirit level and a yard stick.

We want to get the greatest fall in the shortest distance along the stream that is possible. Let us pick out a stretch of the brook that seems to have the greatest fall in the shortest distance. Near the lower end of the riffle, where we think we may locate the turbine wheel, we place the straight-edge at the water's edge and parallel with the bank. The upstream end of the straight-edge rests on a pebble whose top is flush with the surface of the water. We place the spirit level on the center of the straight-edge and then with stones or a stake level up the lower end of the straight-edge until the spirit level shows that the straight-edge is exactly level. We then measure the distance of the lower end of the straight edge above the surface of the water and we find how far the water falls in this ten feet. If the downstream end of the straight-edge is one foot above the water, the fall in that 10-foot section of the stream is one foot. We move the straight-edge upstream exactly ten feet and repeat the measuring process, and continue to repeat the process through any length of the stream desired. If the fall in 100 feet is to be determined the 10-foot straight-edge will have to be moved and leveled up ten times. Any length of straight-edge may be used, just so the board is straight and true. Some streams with abrupt banks may make the application of this simple method a bit difficult, but it can be used in all cases by exercising a little common sense ingenuity.

There are all three of the water questions answered accurately We have learned how fast the stream flows, how much water it delivers a minute and the head of water available. This method may be termed the "dry-foot" method, and it may be used in measuring either small or large streams.

CHAPTER V

THE WEIR METHOD OF MEASURING WATER

THE "dry foot" method of measuring a stream, as described in the previous chapter, is a quick and dependable way of measuring a large or small stream. For a brook or creek, there is another way that perhaps is easier, the weir method. Weir is only another name for dam. The weir method consists of putting

A WEIR FOR MEASURING THE FLOW OF A SMALL STREAM

a small board weir or dam across the stream, after having sawed a section out of the top and middle part of the weir so that all the water of the brook must flow through this sawed section. The depth of the water flowing through this sawed out section in the weir is measured and then by simply referring to the table of weirs on page 35 the capacity of the stream is shown instantly. The picture on this page shows such a weir for measuring a small stream. Should you employ an expert to measure your brook or creek, he probably would bring a current meter and a surveyor's transit or level and then would put in a weir, if the stream were not too

large. He would use up a lot of expensive time at your expense and the results he would obtain would be exactly the results you can obtain without cost.

Let us glance at the picture of a weir and then go down to the brook, put in a similar weir and determine immediately how much horse power is running to waste in that stream. The weir may be made of one large plank or of several pieces of old scrap lumber cleated together. An opening is sawed in the middle of the weir, as shown in the picture, and the weir is set across the stream and is carefully "plugged" with clay or sods to prevent water leaking underneath or at the sides of the weir. The opening is sawed on a slant, beveled, with the sharp edge of the bevel upstream. Say the opening is 30 inches wide and 10 inches deep, or any other width and depth, so long as all the water in the brook flows through the opening, there is no leakage at the bottom of sides, and at the same time the weir dams the brook sufficiently to form a little mill pond three or four feet above the weir. But to be definite, let's have the opening in our weir 30 inches wide and 10 inches deep. Now, two or three feet above the weir we drive a stake in the stream. The stake is marked 1 in the picture on the opposite page. We want the top of that stake just level with the surface of the water. Next we extend a yard stick, or a lath, from the top of the stake to the nearest edge of the opening in the weir. We get that yard stick or lath exactly level by using a spirit level and then we mark on the edge of the weir opening so that that mark is exactly level with the top of the stake. From that mark we measure straight down to the bottom edge of the opening in the weir and our work is done, except for the simple action of glancing across to the page opposite to the Table of Weirs printed there.

Let us say, to be specific, that the distance from the mark we made on the edge of the opening in the weir, to the bottom edge of the opening is 7¾ inches. On the Table of Weirs on the opposite page we notice five columns of figures. At the top of the first column is the word "inches;" at the top of the second column, the cipher, "O"; at the top of the third column, the fraction, "¼"; at the top of the fourth column, the fraction "½", and at the top of the fifth column, the fraction "¾". We look down that first

column, under the word "inches," until we come to the figure 7, remembering that the distance we measured was 7¾. We run a finger across the table to the column that is headed "¾" and there we find the number 8.697, which is the key to determine the rate of flow in this stream. We recall now that the opening in the weir was 30 inches wide, so we multiply the key number, 8.697, by 30, which gives 260.91 and means that the stream flows at the rate of 260.91 cubic feet of water a minute. That is more than enough water under a 15-foot head to run Mr. Rowlands's little 9-inch turbine wheel and generate 5.72 horse power, since Mr. Rowlands's wheel requires only 246 cubic feet of water a minute. And yet this little stream flowing through an opening less than a yard wide; 30 inches wide, in fact; and less than a foot deep, only 7¾ inches deep, develops 5.72 horse power in the smallest turbine wheel.

TABLE OF WEIRS

Inches	0	¼	½	¾
1	0.403	0.563	0.740	0.966
2	1.141	1.360	1.593	1.838
3	2.094	2.361	2.639	2.927
4	3.225	3.531	3.848	4.173
5	4.506	4.849	5.200	5.558
6	5.925	6.298	6.681	7.071
7	7.465	7.869	8.280	8.697
8	9.121	9.552	9.990	10.427
9	10.884	11.340	11.804	12.272
10	12.747	13.228	13.716	14.208
11	14.707	15.211	15.721	16.236
12	16.757	17.283	17.816	18.352
13	18.895	19.445	19.996	20.558
14	21.116	21.684	22.258	22.835
15	23.418	24.007	24.600	25.195
16	25.800	26.406	27.019	27.634
17	28.256	28.881	29.512	30.145
18	30.785	31.429	32.075	32.733

This table is taken from "Electricity for the Farm," by Frederick Irving Anderson, The Macmillan Company. It is adapted from the co-efficients worked out in 1852 by Mr. James B. Francis of Lowell, Mass. This little table is as much a water classic in its way as is Tennyson's "Brook," and although studying a table of figures is not usually attractive, the understanding of the weir method of measuring stream flow is dollars and cents in the pocket of any man who dwells on a small stream. On page 161 we have placed a similar table of weirs from one of our catalogues, because it is graded down to eighths instead of fourths, as used in Mr. Anderson's table herewith.

An adjustment whereby water power may be properly developed for the public good and without working toward monopolies is a vital legislative necessity for the Nation. However, there is no legislative restriction on the small stream power site owner who may put in a home, village or town plant. The conservation acts do not apply to him or his stream and in putting in a home or town plant he has the glad assurance that he is following the most beneficial conservation policy possible.

In this example of enough water flowing through an opening 30 inches wide and 7¾ inches deep to develop 5.72 horse power, we see now why Mr. Rowlands made a mistake in digging a mill race five feet wide and three feet deep. All he needed was a little wood pipe about a foot in diameter and placed below frost line where he could plow right over it without damaging it, or a small wooden or concrete flume. But like most of us he could not realize there is so much work or power in so little water. We base our vague notions of water power on the vague memories of old mills a generation ago that were run by water power. The railroads with cheap coal made possible the larger development of steam power plants and for awhile displaced to some extent the extensive development of water power. Then came a bigger realization of water power's real worth and with it a rapid growth and perfecting of giant plants for producing cheaper electricity and power. So successful was this period of development that a national conservation movement was born of a recognition of the colossal value of water power and of a fear that the country's water power resources might be monopolized by a few long-headed business men. Congress enacted laws to prevent monopoly, thereby doing some good, no doubt, in conserving this greatest national resource for the greatest good of the greatest number, but utterly failing to provide adequate ways of utilizing for the public's good this great resource that is running to waste while it is being so religiously conserved.

CHAPTER VI

The Turbine Wheel

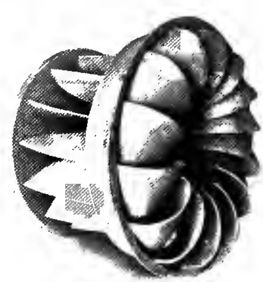
THE most familiar type of turbine wheel is the air turbine, the windmill. An electric fan and the screw propellers of a boat are in effect turbines reversed. Steam turbines in the modern dreadnaughts, torpedo boats, and Atlantic liners and in the highest types of steam plants ashore are exactly on the same principle as the turbine water wheel. The only difference is that one of them uses steam and the other uses water. However, the most efficient type of steam engine, which is the steam turbine, is not half so efficient as the best turbine water wheels, because steam plants require boilers and pipes to carry steam from boiler to engine and in these there is heavy loss in efficiency.

A turbine water wheel is nothing more than a metal whirligig in a box. It has only one working part, the "whirligig" itself, with no array of valves, pistons, piston rings, gears, cams, differentials, timers, cogs, and bearings to get out of order. It is a matter of fine speculation which is the simpler form of power device or machine in the world, the turbine water wheel or the rim-leverage water wheel. Certainly the turbine water wheel is the most durable and efficient power producing machine man has yet invented and developed. We have referred to the turbine wheel itself as a "whirligig," but the correct name for the turbine wheel is "runner." The name describes it, for it most surely does run. The runner has a hole in its center and in this hole a shaft or axle is fitted. The shaft turns as the runner turns. The shaft projects up through the water of the turbine wheel pit of the vertically mounted wheel such as Mr. Rowlands uses and at its upper end is connected by gears and belts to the machinery to be driven. If the wheel is mounted horizontally the shaft projects out through the wheel pit or out from one or both ends of the turbine case and is connected at either one or both ends of the turbine case, directly or indirectly, with the machinery to be used. The picture on the following page shows a Hunt-

Francis Runner, a typical runner of the highest type for developing power from high heads of water. On the right hand side of this page is a picture of a Hunt-McCormick Runner designed to develop the maximum power under low heads and the most usual conditions. Set either of these runners in a barrel to fit, wedge a steel shaft into the hole in the center and you have a turbine water wheel, rough and crude, it is true, but beautifully illustrating the utter simplicity of the machine, merely two pieces of metal in a barrel.

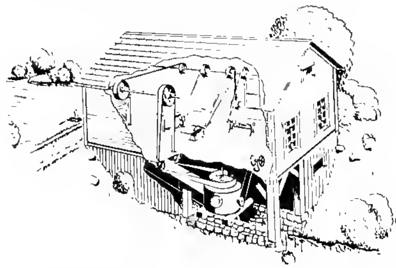
A Hunt-Francis Runner, the Heart of the Turbine Water Wheel for High Heads

It is the curve of the runner's buckets, those fourteen or fifteen metal blades that radiate out from the center of the runner, much like the petals of a flower, that give the runner its efficiency. Bend those buckets the tiniest fraction of an inch either way at any point, and at once you have cut down the efficiency of the wheel. You can check up that assertion most emphatically by bending the blades of an electric fan. Flatten the electric fan's blades or twist them farther around and you can eliminate the ability of the fan to throw out a current of air. However, the thin, flexible blades of an electric fan, set with only a practical and fair degree of accuracy, should not be compared with the solid, heavy, thick, tough and unyielding buckets of the turbine runner, set and curved at every point with the highest mathematical skill and proved out by many years of actual working and by exhaustive tests. The buckets of the Hunt-Francis Runner have been developed, through years of work, to absorb every atom of power it is possible to take from high heads of water. In a like way the Hunt-McCormick Runner has been developed to take all the power that is to be had from lower falls of water and the more usual conditions of water power development. The water crowds into these runners through gates and in a solid, unending



A Hunt-McCormick Runner for Usual Conditions in Water Power Development

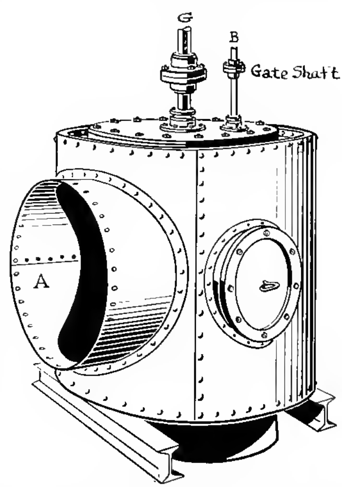
mass presses and shoves against every tiny atom of surface of the runners. The runners react to this constant pressure and move, revolve, and as the pressure of the water upon them is smooth, constant, solid, unending, the revolving of the turbine runner is absolutely smooth and without the tiny jars and jerks that always must be present in the most perfect of gasoline motors or in reciprocating steam engines.



A Home Power Plant and Machine Shop with Vertically Mounted Turbine Wheel in a Case Beneath the Power House

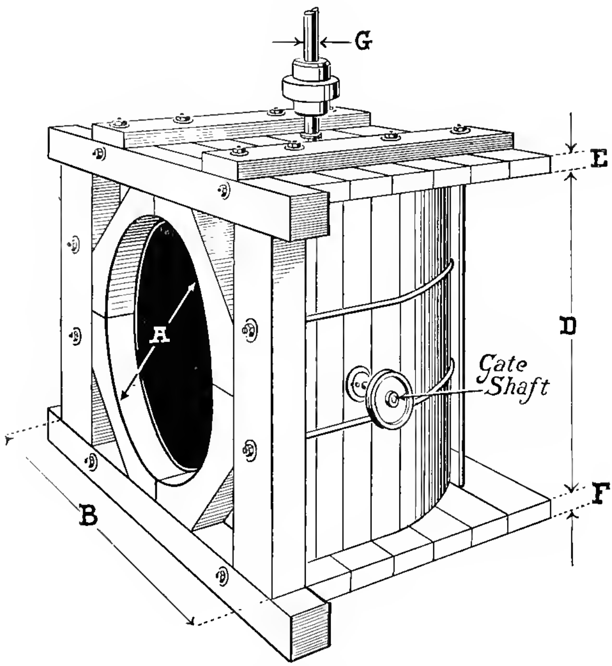
Hence turbine water wheels are termed reaction wheels, while rim-leverage wheels which operate by the combined kick or blow of the water striking upon them, and the gravity weight of the water carried down by them are called impact-gravity wheels.

On this page are shown above, a picture of a little turbine wheel home water power plant, with a vertically set turbine wheel in an iron case immediately beneath the power house. At the left of the power plant is the dam, with pipe carrying the water from the dam to the wheel. A belt making a quarter turn transmits the power from the turbine wheel to a line shaft on the ceiling of the house and operates through belts and pulleys the machinery in the power house. Two timbers on a rough stone wall support the turbine wheel. The second picture is an enlarged diagram of the iron case used for this turbine. A is the water intake, G the power shaft and B the shaft to open and close the gates and control the flow of water to the wheel. The water discharges through the bottom of the



An Inexpensive Iron Case for Vertically Mounted Turbine Wheel

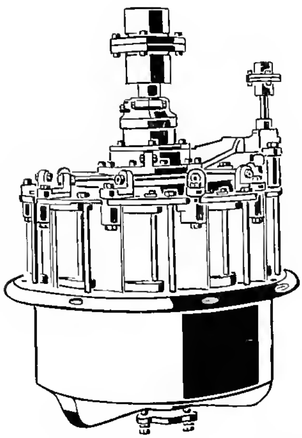
turbine case. In this picture two I beams support the case and wheel, but the wooden timbers shown in the picture of the power plant, would serve as satisfactorily. This turbine case could be set in a corner of the power house just as well, but in this case it is placed lower down, beneath the power house, to get a higher head of water in the short fall from the dam to the wheel.



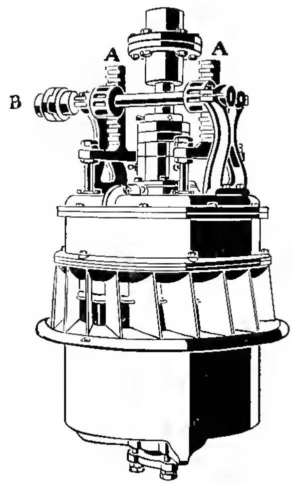
WOOD TURBINE WHEEL CASE, THOROUGHLY SUBSTANTIAL BUT WITH A MINIMUM OF COST

A sturdy and cheaper turbine wheel case for this little home power plant is shown in the illustration on this page. It may be set beneath or inside the power house. As shown here A is the place where the pipe carrying the water joins onto the case, G is the power shaft and the wheel in the center, labeled "Gate Shaft," is attached to a small hand wheel by a rope to enable the flow of water to the wheel to be quickly and easily controlled by a small hand wheel.

A turbine runner could be set in a rain barrel and be made to operate, we said in illustrating the simplicity of the mechanism, but a more mechanically perfect arrangement than only a rain barrel turbine wheel case must be provided, so the wheel is equipped with gates to control the flow of water into the runner. So, just as the turbine runner has been perfected to meet different conditions, so the gates and casings have been adapted to furnish the best service under particular or varying requirements. On page



Turbine Wheel in Balance Gate Casing

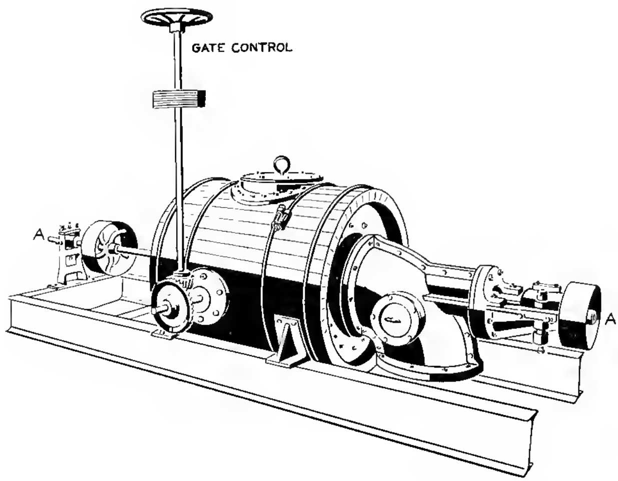


Turbine Wheel in Cylinder Gate Casing

16 was shown a picture of a turbine wheel mounted in a pivot gate casing. On this page are drawings of a Balance Gate Casing, at the left, and of a Cylinder Gate Casing, at the right. The runners are inside the casings and, of course, cannot be seen. Whatever the form of gate used it should be remembered that the gate is only a throttle, to start, stop, and regulate the speed of the wheel. The gates are designed to let the water into the runners in a solid volume, with a minimum of loss in friction and without eddy currents.

So far we have looked at the turbine wheel largely as being set vertically. This sometimes is the more convenient arrangement

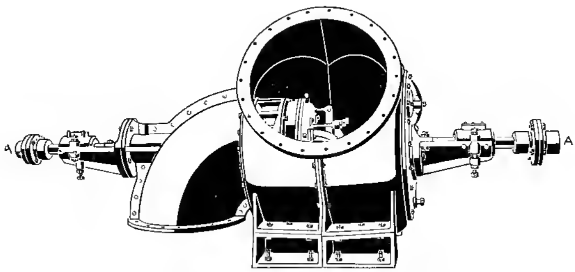
in small plants, as with Mr. Rowlands, who simply stuck a small Pivot Gate Casing and its runner in the bottom of a box of water and without using a pipe or case as shown in the picture on page 16. A turbine will develop as much power mounted vertically as when mounted horizontally. But the vertically mounted turbine wheel usually has to have a quarter turn belt connection or a crown gear to transmit its power to line shaft or to a machine. Quarter-turn belting and crown gears, no matter how well ad-



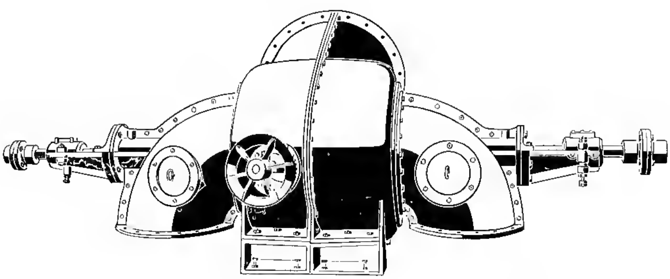
Turbine Wheel in Horizontal Wood Case

justed, eat up some power because of friction. The horizontally mounted turbine wheel, on the other hand, if connected by belts, does not require the quarter-turn arrangement, and thus one small source of friction and power loss is eliminated. Neither does it require crown gears, and better still it may be keyed direct to the machine it is to drive. When connected by belt or cable the most direct connection is available with horizontally mounted turbine wheels and thus loss in friction is greatly reduced. On this page is shown a horizontally mounted turbine wheel in a substantial and inexpensive wooden case. It will be noticed that the power shaft extends through, from A to A, and that the shaft has pulleys at both ends for belt connections with electric generator, line shaft,

cream separators, saws, feed mills or any other form of stationary machinery that may be required. Such a horizontally mounted turbine wheel could be placed in the corner of the kitchen of the average country home and be operated entirely successfully without interfering with the regular work of the kitchen, if the machinery driven by the turbine wheel were not in the way. The turbine itself, in the sizes for small plants, would not occupy as



Turbine Wheel in Horizontal Steel Case

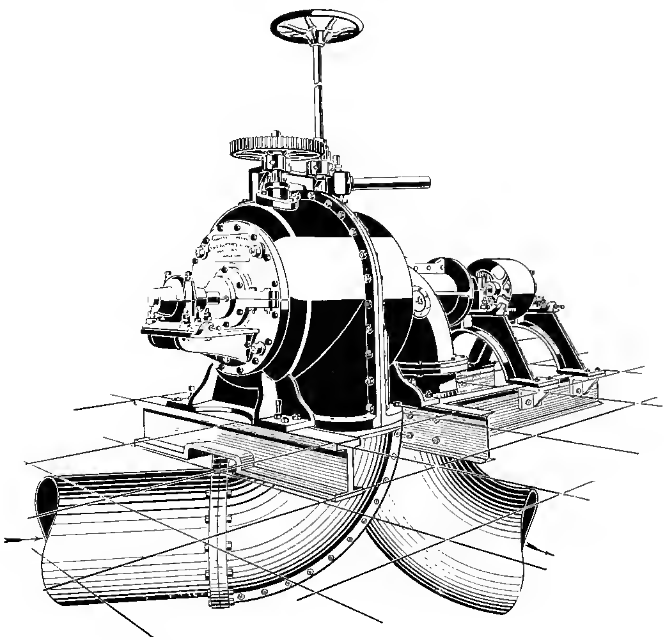


A Pair of Turbine Wheels in Horizontal Steel Case

much space as a piano and all the equipment it would require would be a wood or steel plate pipe through the wall or floor of the kitchen, to supply it with water, and a discharge pipe through the kitchen floor to take the water away. The same runner or turbine wheel may be mounted horizontally in a still more refined manner, in a steel or cast iron case, as shown in the first picture below, or a pair of wheels may be mounted together as shown in the second picture on this page. The opening shown in the top-

center of the upper picture is where the pipe joins the case. The view of the pair of wheels is from the opposite side.

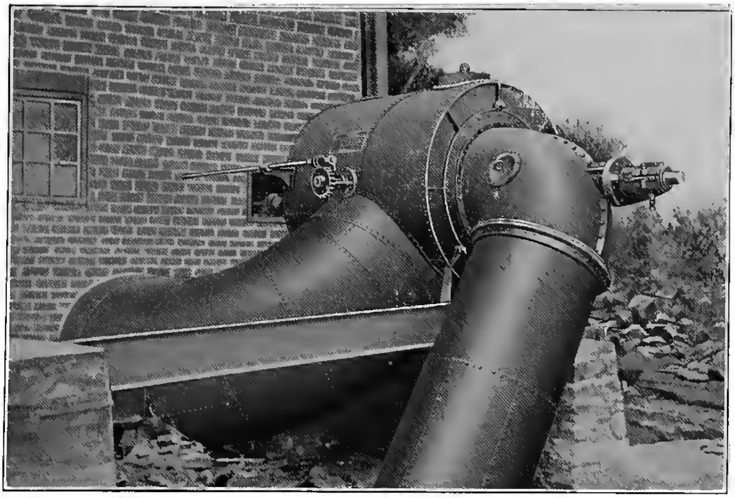
Not only is there a water wheel for every stream, but there is an arrangement that fits most practically every particular need or peculiarity of any water power development, anywhere, large or small. On this page is a turbine wheel with both discharge and supply pipes entering the wheel case directly underneath the floor.



A TURBINE WHEEL OUTFIT TO BE CONNECTED TO CITY WATER MAINS FOR OPERATING AN ELECTRIC GENERATOR

The picture on the opposite page shows our novel arrangement of mounting a turbine wheel on a horizontal shaft. It is wholly outside the building but is controlled by a gate shaft from inside. The water is carried to the wheel by a pipe or penstock running under the basement floor, entirely out of the way and permitting the floor above to be given over entirely to the turbine shaft and the machinery it supplies. By this method all the effective head of water available was conserved. This installation,

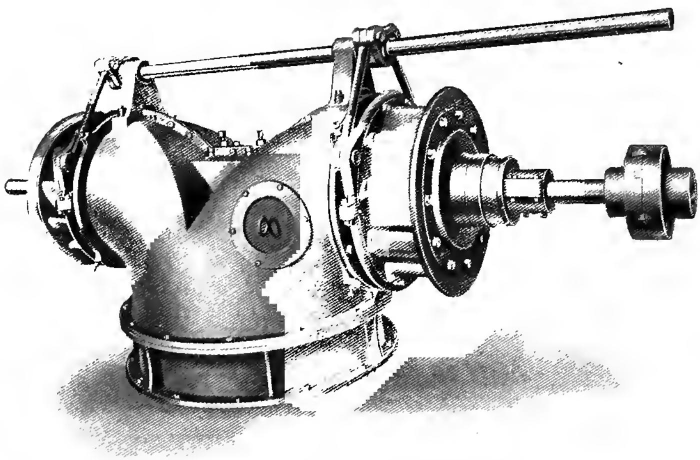
too, replaced an old, vertically mounted wheel and did away with its old mill race, clumsy wheel pit and its power-eating and space-occupying gears. No matter what the arrangement or type of turbine wheel that is installed, from the most inexpensive arrangement of a wheel and gate casing submerged in wooden box, the cheap little wooden case inclosing a turbine wheel, or the more



TURBINE WHEEL MOUNTED ON THE OUTSIDE OF A POWER HOUSE

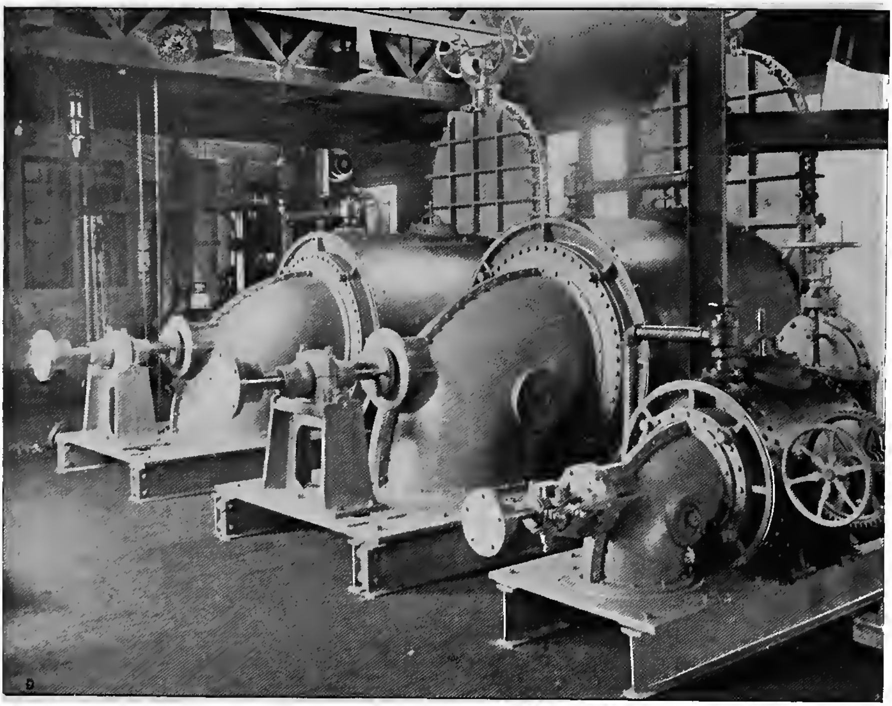
refined mounting of a pair of wheels in a scroll case shown in the lower picture on page 43, or in any other of a variety of forms, the water motor itself, the runner, is the same; and the little, inexpensive turbine wheel is just as efficient, just as durable just as able to fill 100 per cent of its intended purpose, as are the larger and more refined mountings. In these pages we are trying to show plainly and fairly the opportunities in the development of the small stream. On page 176 are suggestions, the answers to which will enable the Rodney Hunt Machine Company, Orange, Massachusetts, to reply specifically and accurately as to the possibilities of developing home or small town power sites. The Rodney Hunt Machine Company will be glad to advise as to methods of harnessing the water power of any stream, large or small.

On this page is a picture of another arrangement of a pair of turbine wheels, with Hunt Balanced Gate on a horizontal shaft in a depressed top T Center draft chest. A few of these arrangements are shown here, not that they may directly benefit the investigator of home or small town water power development, but that he may glimpse the wonderful perfection turbine water wheels have attained. On pages 47 and 48 are pictures of larger water power plants.



ANOTHER FORM OF TURBINE WHEEL MOUNTING—NO MATTER HOW PECULIAR AND COMPLEX THE NEEDS AND CONDITIONS OF A WATER POWER PROJECT MAY BE, THERE'S A WATER WHEEL TO FIT THEM.

Typical Large Installation of Turbines in Open Flume



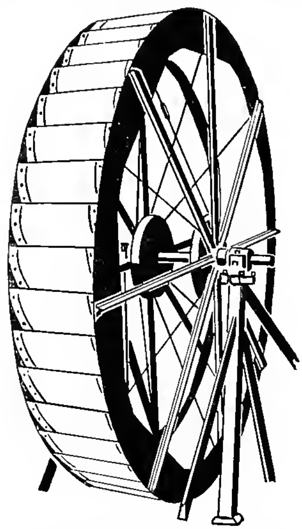
TURBINE WATER WHEELS FOR A SOUTH AMERICAN POWER PLANT

A turbine outfit to develop 3,500 horse power for the Cordoba Electric Light & Power Company, Cordoba, Argentine Republic, South America. An unusual feature in this plant is shown in the two vertical sliding gates in the background. These gates open and close the water supply pipe leading to either unit. The picture was made in one of our setting-up rooms before shipment. Later we supplied the same company with a similar plant to generate 2,000 horse power.

CHAPTER VII

The Rim-Leverage Wheel

MAN'S first efforts in developing power and lifting water were with water wheels, overshot and undershot wheels, more correctly termed Rim-Leverage Wheels. In Syria and Egypt today there still are in use the same clumsy, inefficient type of water wheels used there thousands of years ago. The ancients seemed to realize fully the wonderful willingness of water to work, but they were powerless to develop it, for they lacked the technical knowledge that is the heritage of the present scientific age. In comparatively recent years the industrial world, particularly the English, spurred by the great strides in manufacture that followed the invention of the spinning jenny, sought to develop water power by increasing the size of these old wheels hugely. On the Isle of Man, at Saxy, is such a wheel entirely of wood and 72½ feet in diameter, the largest water wheel known. On page 50 is a picture of a Philippine water wheel, showing how the other side of the world has tried to do its part in making use of the billions of barren horse power that run to waste in the earth's streams.



A Rim-Leverage Water Wheel, the Cheapest Practical Power Developing Machine yet Devised.

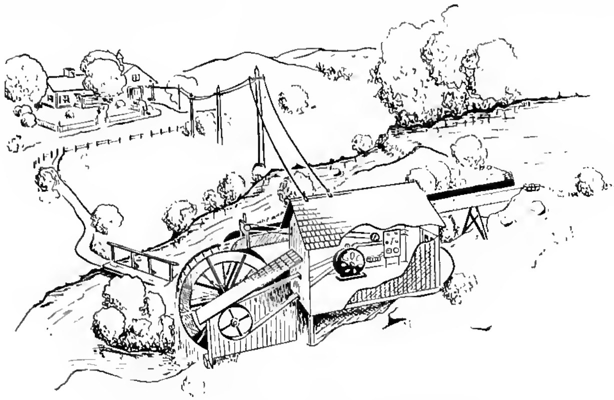
Yet despite the age-old knowledge and use of water wheels it remained for a present generation to see born an almost mechanically-perfect Rim-Leverage Wheel, capable of standing alongside the best that electrical, steam, and internal combustion engineering has produced in efficiency, practicability, durability, and genuine worth. The picture of the little home water power electric plant on page 51, shows such a water wheel creation as

typified in the Hunt Steel Rim-Leverage Wheel or in the Hunt Wood Rim-Leverage Wheel. Between the picture on this page of the awkward, straggling contrivance towering into the air, and the little water wheel pictured on page 39, lie thousands of years of human progress. The modern, scientific, little Rim-Leverage Wheel, as shown in operation in the small home power plant on page 51, and as pictured in detail on page 49, shows a close-knit,

A PHILIPPINE WATER WHEEL
REPRODUCED BY COURTESY OF LA HACIENDA, BUFFALO, N. Y.

perfectly balanced machine, rearing a slender height of not more than six feet and smaller in diameter than the drive wheels of many railway locomotives. It is made in three diameters, 4, 5, and 6 feet, and with a "tire" width, or face, of only 6 inches where the wheel is to be used only to drive a pump for supplying a complete water works system of a large or a small country establishment. Where the Rim-Leverage Wheel is to supply power for an electric generator and other machines, as well as to drive a pump, the diameters of the wheels are the same, 4, 5, or 6 feet or more, but the face may be as much as 6 feet. The wheel 6 feet in diameter and with a face of 6 feet, with a proportionate flow of water, of course will furnish much more power than the wheels that are 4 or 5 feet in diameter.

These modern Rim-Leverage Wheels were developed, not by the mistaken plan of seeking to overcome defects and crudities by mere size, but by making a very small wheel mechanically perfect. You perhaps have noticed how teeth of the cogs in the gears of an automobile, or in any other well made machine, are



RIM-LEVERAGE WHEEL OPERATING A HOME ELECTRIC AND POWER PLANT

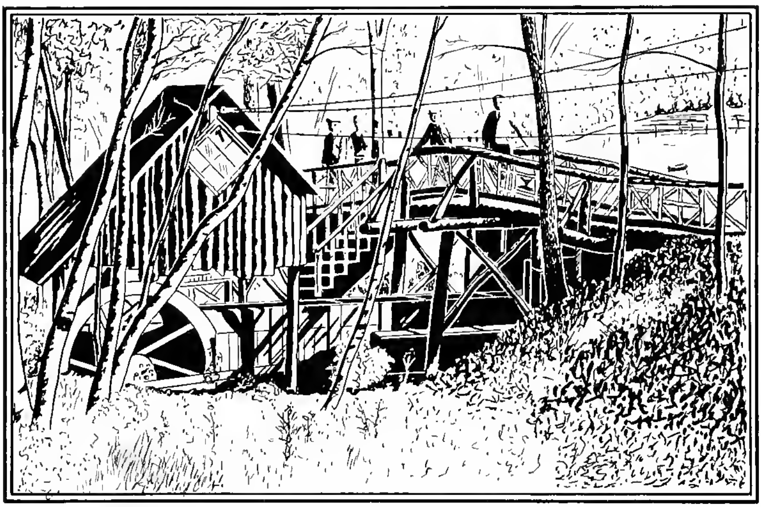
curved. The curve of those cog teeth is not by guesswork or accident, but entirely according to carefully determined mathematical formulas so that the interlocking teeth roll or revolve on one another with a minimum loss of power in friction. So it is with the blades or buckets of a Rim-Leverage Wheel, which are curved, spaced and set with the utmost skill of engineering practice backed up by years of practical experience and constant testing. The wheel is balanced and its buckets curved and set so that the wheel takes every possible bit of power from the falling water.

It is because of this perfect mechanical development that the Rim-Leverage Wheel is practical for tiny rivulets having a flow of only a few gallons of water a minute. To make clear how very tiny a rivulet will successfully operate a Rim-Leverage Wheel and pump attachment, take three random examples of the range of work of the three smallest wheels:

A wheel only 4 feet in diameter and with only a 6-inch face will pump 800 gallons of water a day to a height of 50 feet and almost any distance for farm needs, if but 10 gallons of water a minute are supplied to the wheel.

Or, let 50 gallons of water a minute, which is a very small flow for even a little spring branch, run down a tiny wood trough to a Rim-Leverage Wheel 5 feet in diameter and with a 6-inch face, and the wheel will pump 2,500 gallons of water a day to the top of a hill 100 feet higher than the pump and practically any distance.

Or, let there be only the tiniest sort of trickle tumbling onto a 6-foot wheel with a 6-inch face, a trickle of only 6 gallons a minute, and the wheel will pump 360 gallons of water a day to the top of a hill 100 feet high and on the far side of the valley from the pump.



A Modern Rustic Electric Power Station

These Rim-Leverage Wheels and pump combinations will lift water to a height of more than 300 feet and to practically any distance. As the wheel is small, the sizes used in pumping water are inexpensive, easy to install, almost indestructible and beyond doubt the best and most dependable power pump yet devised. They have a big advantage over windmills, rams, or power pumps of any type. They will use impure water from one stream to operate a pump to deliver water from a distant spring, a pond or from a stream of pure water that may be a considerable distance from the wheel itself. Unlike the windmill they do not have to be placed over, or even near, the supply of water they are to pump.

Their range of capacities is far beyond that of windmills or hydraulic rams. Other advantages of the Rim-Leverage Wheel and pump combination are:

It is simple and needs no large, expensive piping.

It has no expensive valves to wear out.

It has low repair expense.

It is adaptable to a variable flow of water with equally satisfactory results.

It is noiseless.

It is made durable and almost everlasting.

It is a picturesque ornament to any rural landscape.

It Pumps Water to a Height of more than 300 Feet and to Any Distance

Hunt Rim-Leverage Wheels are made with steel rims or with wood rims. Both give equivalent results in work. The chief difference is that the wood rim wheel is cheaper than the steel. These smaller wheels with only 6-inch face and the pump combination afford fire protection and a constant and adequate water supply for any country establishment. They may be used to pump through service pipes to the household, barns, and grounds, or they may be connected to a pressure tank in the basement or in a cellar, or buried below frost line out of doors, or to an elevated tank, thus providing a reservoir of water under pressure for fire protection and all uses. Whatever the size of the Rim-Leverage Wheel or the purpose to which it is put, either pumping water, or furnishing power it is wholly dependable. The frame supporting the wheel is anchored to a pair of wood timbers or sills with lag screws. Anyone can install the wheel. As the sills are placed to be just barely covered with water, they cannot rot and thus the whole outfit is almost everlasting. The supports of the wheel are large and rugged. They carry liberal sized bearings arranged for self-oiling cups. The water may be led to the wheel through a wood trough, chute or pipe, or through an iron chute or pipe or a concrete flume. As the wheel has no gates or valves to be obstructed, trash or rubbish that will flow through the pipe or trough will run over the Rim-Leverage Wheel.

Where the spring branch or brook has sufficient flow, the larger Rim-Leverage Wheels are excellent to operate home power plants as well as to pump water. They can operate entirely

successfully under much smaller volumes of water than can the turbine water wheel. They, of course, are limited as power producers, but are adequate for the average electric plant of the country home. For pumping water, they undoubtedly are as perfect an arrangement as can be found. The pump parts are of brass, durable and simple so that the necessary packing in all pumps does not need frequent repacking. The suction pipe from the spring or pond supplying the water to be pumped, not the water that operates the wheel, should be ¾ to 1 inch in diameter. The delivery pipe, from pump to points to be supplied, should be ½ to 1 inch in diameter. Galvanized iron pipe is recommended. Both pipe and pumps should be put below frost line to prevent them from freezing.

The quantity of water for household use may be estimated at about 200 gallons a day for a family of six. With a pump operated by water power no limit within reason need be placed on the quantity of water used by the household for any purpose, since it costs nothing to run such a pump outfit and it does not wear out. For farm animals the approximate allowances of water daily are:

Each cow 12 gallons
Each horse 10 gallons
Each hog 2½ gallons
Each sheep 2 gallons

You can readily determine the suitable pump and wheel requirements for your needs by sending the answers to the following questions to the Rodney Hunt Machine Company, Orange, Massachusetts:

Number of gallons flow a minute of power stream?

Number of gallons flow a minute of spring supplying the pump, if the same stream is not to be used to furnish power and for pump, too?

Total flow of power stream in feet?

Distance in which flow is obtained?

Height to which the water is to be delivered?

Approximate flow of spring in feet?

Approximate distance from spring to pump?

Distance water is to be delivered?

Estimated number of gallons required each day?

What water supply system is now being used?

CHAPTER VIII

Electricity in the Home

MEASLES, that childhood ailment, known in almost every home the world over, has one characteristic in common with electricity. The world does not know what either of them is. It only knows how to handle them, to derive innumerable benefits from one, to curb the other with drawn shades, warmth and a liquid diet.

No, not a far-fetched comparison! Only an illuminating example to show how inert is the stock argument of the man or woman who hesitates in having the money-saving convenience of a home or town water power plant and electricity because he does not "understand electricity." No one knows what electricity is. No one knows what causes the measles. The point is that we do know how to handle them; electricity, at least, in such a practically perfect and safe way that it is the best thing man has done for himself with his mechanical genius. Although the greatest authority on electricity does not know what electricity is, he and his kind have perfected and simplified electrical apparatus until the most inexpert man can install and operate a home electric light and power plant successfully and easily, with only a few plain, printed directions to guide him.

There are two general types of electric generators. The word "generator" has succeeded the word "dynamo" as the name of a machine that develops electric current. These two types of generators are called direct current generators or alternating current generators, according as they produce the two most used kinds of electric current, direct current and alternating current. All electric batteries produce only direct current. As the storage battery is a convenient part of the home or small town electric plant, the use of a direct current generator eliminates the necessity of changing the alternating current to a direct current, as would happen if an alternating current generator were used to charge the storage battery. Still another reason why direct current

generators are used almost exclusively in small town and home electric plants, instead of the alternating current generator, is that the direct current generator costs less than the alternating current generator and is about half as complicated. The alternating current generator must be equipped with a small but complete direct current generator to excite its magnets. The direct current generator is complete in itself. Alternating current generators are used where the current has to be carried a considerable distance

While we indicated in the beginning paragraph of this chapter that electricity was as easy to have as the measles, so far as any expert knowledge might be required, there is certain very definite knowledge on the producing and handling of electricity that any user or producer of electricity in the home will find useful and interesting.

A common horseshoe magnet, such as children play with, contains an element called magnetic flux or "current." This flux is not the same thing as the electric current we are familiar with in different forms that is used in furnishing light, driving machinery, electroplating the pages of this book, plating silverware and doing a thousand other useful things. No one knows what this flux is, or what electric current is. That is the hidden part of electricity. But whatever flux and current may be, we do know how to handle them, to make them work at gigantic tasks or to shear their strength at will. Take a child's toy horseshoe magnet in one hand and a piece of copper wire in the other hand and wave the wire up and down between the ends or two poles, the positive and negative poles of the magnet, and you have an electric generator. That's all any electric generator is, an electric conductor, such as copper, passing through the flux that flows between the poles of a magnet.

A few years ago "magneto" was a common term in the automobile world. A magneto is a simple form of the electric generator. It consists of one or more horseshoe magnets. At the open end of the magnet or magnets an electric conductor, commonly called an armature in generator construction, is placed so that it may revolve between the poles of the magnet. As it revolves the armature cuts the flux or lines of force, that "flow" constantly between the poles of the magnet, and thus electric current is produced. The telephone that you have to "ring up" and "ring off," used in many rural telephone systems, has a similar magneto,

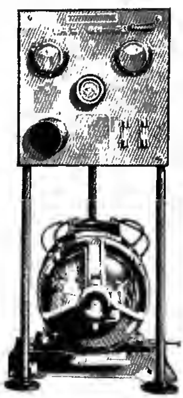
or electric generator, in each telephone box. When you turn the little crank at the side of the telephone you turn an armature inside the box. As you turn that crank your hand supplies to the magneto the necessary motive force exactly as does water power, a steam or gasoline engine that operate a larger electric generator.

Automobile electric units have advanced from the magneto type of generator to the abler, more perfect type used in home electric plants wherein the horseshoe magnet is replaced with another kind of magnet, usually several of them in each generator and referred to as electro-magnets. These electro-magnets consist of fine wire wound around steel or iron cores. The greater number of coils around the magnet, the stronger the magnet. To "excite" the electro-magnets; that is, to make them stronger, a part of the current developed by the generator is sent or shunted through the coils of the electro-magnets. Such generators are termed shunt-wound generators and are the most generally used form of generators today. In series-wound generators all the current of the generator is sent through the field coils. The type of winding, however, is a technical problem for the experts. We'll leave it to them, since most of us have some other specialty to worry over.

While waving a wire between the poles or ends of a toy magnet in reality forms an electric generator it is mechanically a very imperfect generator. There must be a better way of doing it, so, an electro-magnet or several of them, are placed around a common center, the shaft of the generator. On this shaft an insulated drum or cylinder is fastened so that the drum revolves between the poles of the magnets with only a fraction of an inch of air space between the circumference of the drum and the poles of the magnets. The drum is wound with insulated wires, which are the conductors that cut the magnetic flux as the drum revolves, and thus produce electricity. The ends of these conductors are soldered into a much smaller "drum" that is fastened onto the same shaft and that is called a commutator. The commutator collects all the electric current developed and delivered by the conductors as they cut the magnetic flux. Carbon "brushes" are placed to touch the commutator as the commutator whirls around with the drum and they pick up the electric current the commutator collects. Wires take the current from the brushes to wherever it is to be used.

To revolve the armature between the magnets requires power applied to the shaft of the generator. There are two main ways of applying this power and thus generate electricity. Either the shaft of the generator is keyed to the shaft of a turbine water wheel, or pair of turbine wheels, which is direct connection. Or, the generator is connected to the turbine wheel or rim-leverage wheel by belt or cable drive or to a line shaft operated by the water wheel. Either style of connection may be made with large or small water wheels and with either type of generator, direct or alternating current.

The picture on this page is of a small direct current generator, and switchboard, especially designed for the home plant. Shown here, it is ready to be belted to a rim-leverage or turbine water wheel producing two to five horse power. If the water wheel develops more power, as the plant may use considerably more power to operate other machines, too, the installing of the generator need not interfere with the working of the rest of the plant, as the generator may be belted to a line shaft run by the turbine wheel and thus be operated while the whole plant is in full running. The small generator fits into the larger power development, since it takes only a tiny bit of power, and since it increases the efficiency of the plant, just as electricity will increase the efficiency and convenience of any home or work by providing adequate light. As it stands the outfit pictured here is a complete electric plant. At the bottom of the picture is the generator, compact, simple and so safe that a child can operate it without danger since it develops only 40 volts. In its simplicity, durability and efficiency of operation it answers fully that ugly and common, but expressive phrase, "fool proof." Above the generator, is the switchboard, supported on iron pipe standards, a black, marine-finished panel of slate bearing all the necessary apparatus for complete control of the current. It is in all effect a simplified and perfect miniature of the big city electric plant. We called it a complete plant, and so it is, except that for home use and in small town and village electric plants it is more convenient to add a storage battery to the equip-

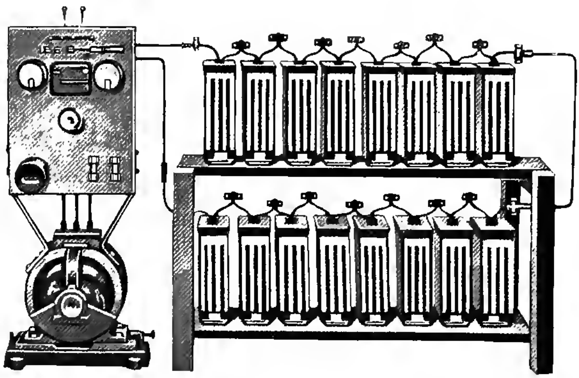


ment. With a reserve supply of current in the storage battery it is not necessary to visit the power plant and start the generator whenever current is wanted. Only at odd intervals, when the battery gets low, is it necessary to step over to the power plant, start the generator and recharge the battery.

Where there is no storage battery the generator must be run at all times current is used, even if the current needed is for only a small incandescent light. It isn't always right handy to visit the power plant in the middle of the night, or in the day time, to start the generator, so solely for convenience the storage battery is added to the equipment of the home plant. So far as money cost in operating goes, the water wheel owner could run his electric generator practically all the time. Electricity made by water costs nothing. But for the sake of convenience the reserve supply in the storage battery is highly desirable at times. Of course, if the home plant is operated by gasoline engine or steam, the storage battery is absolutely the salvation of the home or small town electric plant. It costs money to make electricity with gasoline, kerosene, and steam.

The picture on page 60 is of a generator and switchboard, and a 16-cell storage battery in a battery rack. Connected with a rim-leverage or a turbine water wheel it is the ideal electric plant for the country home. There are two popular sizes meeting usual conditions, one a 55-light and one a 60-light outfit, either of which is very elastic in application to the needs of a small home or a larger country establishment. In addition to supplying all the electricity for lighting needed in the buildings and grounds of the average country home, the plant furnishes power for washing, churning, sewing, vacuum cleaners, fans, and heat for ironing and cooking. These two outfits fit as nearly as possible the general run of needs of the country home the world over. They are standardized particularly for home use although larger size outfits are often used. Where more electric current is desired, either for a larger country establishment or to furnish light and power for a whole community, stores, shops, offices, the water power owner can easily enlarge his electric plant to meet those needs. The Rodney Hunt Machine Company would be pleased to suggest additions to the home plant shown here to increase

its scope of usefulness, or to suggest other electrical equipment for the larger or special needs no matter what the size of the plant contemplated.



The switchboard shown in the two previous pictures of home electrical units could be less substantial and cheaper and perhaps give satisfactory service, but it would not meet the requirements that engineers have specified for the fire insurance writers and so would prevent its owner from obtaining the cheaper fire insurance rates that his water power electric plant entitles him to. It is a piece of thorough workmanship. At the top is a double-throw, single-pole, knife switch for starting. Just below are two dials: one an 0-50 voltmeter; the other, a 30-ampere ammeter. In the center is a back-of-board type field rheostat for regulating voltage and maintaining the correct charging rate for the battery. Plain and simple directions on a small panel, two glass inclosed fuses and an automatic cut-out to prevent current flowing from the battery back into the generator complete the board's equipment. The battery consists of 16 sealed glass jars, each cell or jar generating two volts, 32 volts in all. The generator develops 800 watts of 20 amperes and 40 volts.

The average man or woman isn't called on to use such terms as "watts," "amperes," "volts," and "ammeters" frequently enough to be very familiar with them. But since he cannot escape putting money into them directly or indirectly, if he lives or appears anywhere outside of a wilderness, let's straighten these

terms out once and for all. A "volt" is a unit of electro-motive force referred to by technical men as e. m. f., but we will call it pressure. It was named after a man, Volta. Amperes we will call quantity of electricity. That is not an exact parallel or analogy, but it is near enough for practical illustration. It is named after a man, Ampere. An ammeter is an instrument for recording amperes or quantity of electrical current. Voltmeters record the pressure of electrical current. Watts is the power of electrical current. It, too, gets its name from that of a leader in electrical research. To make the foregoing clearer, we will say that 20 cubic feet of water (quantity) produce a certain horse power when under 40 pounds pressure (volts). Then 20 amperes, quantity, under 40 volts, pressure, produce so many watts, power. How many watts? Eight hundred watts, since 20, the quantity, multiplied by 40, the pressure, give 800, the power of the home plant electric generator described here. A kilowatt is 1,000 watts and is equal to 1.34 horse power. Or, 746 watts are equivalent to one horse power.

On a calm day a child may wade waist deep at the sea shore without danger. All the water necessary to drown an army is close at hand, but the child suffers no harm. There's no pressure, no "voltage." But let a strong man wade knee deep in a little mountain stream ten feet wide and he is helpless, swept off his feet. The tiny, rushing flow of water has pressure, voltage. So with this home electric plant, it has all the quantity of electricity needed, yet at such low voltage or pressure, 40 volts at the generator, that the current gives no shock and is scarcely perceptible. Many city lighting plants carry 110 volts on home lighting circuits and are considered to be without danger. That voltage gives only a slightly unpleasant shock. Still other city home lighting circuits carry a voltage of 220, which is not considered a menace to human life. However, 200 volts is a safe point to begin with in considering electrical pressure dangerous.

The home plant generator develops 40 volts while the battery delivers only 32 volts. This margin is made purposely liberal to care for the inevitable leaks in every piece of electrical apparatus that ever was made, and to insure a generous current to the battery. The 16-cell battery has one more cell or jar than usually

is supplied in similar outfits. This gives two extra volts that take care of the "drop in the line" caused by the fact that resistance in electrical conductors absorbs some electricity no matter if the wire carrying the current is no more than a foot long. The battery cells are sealed, too, which is a precaution not always taken. Dust settling in the jars will lower a battery's efficiency. Batteries are of two kinds, primary and storage. The primary battery develops current by the reaction of chemicals. When it has delivered its charge it is dead forever. The storage battery is made by immersing two electrical conductors, called electrodes, in a conducting solution, usually pure water and chemically pure sulphuric acid. The solution is called the electrolyte. Before the storage battery can operate it must be charged with a direct electric current. This current sets up a chemical action in the electrolyte, produces a sort of tension that the battery tries to throw off and return to its original state before the charging current was introduced. The battery sends current into the electrical circuit in trying to "settle back" to its original state. When a storage battery has delivered a large part of its charge its activity is renewed by being recharged from the generator.

Electric irons and ranges and electric motors that develop more than ¼ horse power should not be operated from the battery alone. The generator should be running while they are in use, because they discharge the battery too rapidly. This holds true for any small home plant, whether operated by gasoline, kerosene or water motors, and it is here again that the rim leverage wheel and the turbine wheel have a distinct advantage in the home power plant. It costs nothing to run the generator and make electricity with water. If after the current is turned off from motors, irons or electric ranges, and no current is being used, some one forgets to stop the generator, no harm will follow. The battery will be "floating on the line." The condition would be somewhat like operating a small, disconnected centrifugal pump in the bottom of the Mississippi River. The pump would churn up a lot of water within itself, but it wouldn't make a ripple on the surface.

The care of batteries requires chiefly one thing, that the cells be kept filled with distilled water. Rain water that has been caught in a wooden container may be used if distilled water is not

available. But, spring, well or ground water of any kind should not be used. Full directions are furnished with each battery and a hydrometer, which is a simple glass instrument resembling a thermometer, is provided with each outfit. By placing the hydrometer in a cell the strength of that cell is immediately apparent. How simple is the care of batteries is shown by a recent incident, when a city man was showing a country cousin the sights and stopped at a garage to have his automobile battery tested. An "expert" came out and very expertly poked a hydrometer into each cell of the battery. He said the battery tested 1200. The country cousin admiring the man's deftness casually asked, "Twelve hundred what?"

"Twelve hundred volts," replied the "expert," and neither he nor the city man understood why the country cousin laughed. The country cousin had a home electric plant of his own and knew that the 1200 indicated on the hydrometer referred to the specific gravity of the electrolyte of the battery and thus indicated the strength of the battery. The little 6-cell battery of that motor car developed a current of only 12 volts. Yet that "expert" was a good mechanic, a worth-while citizen and had been "experting" on motor cars several years very satisfactorily in a practical way. The automobile proves the absolute practicability of the home electric plant, for the automobile carries a complete electric plant and is practical and dependable under the clumsiest hands and the most inexpert intelligence. Still the automobile electric plant can hardly be compared in durability, simplicity, and efficiency with the home electric plant. The motor car's batteries last about two years on an average while the home lighting plant battery may last seven, eight or even ten years before having to be replaced.

Sometimes a reducing regulator for charging automobile storage batteries, is arranged to be mounted on the wall and connected to the switchboard of the home plant described here. It may be used to charge automobile storage batteries of 3, 6, 9, 12, or 15 cells at any rate from 5 to 20 amperes. This resistance unit illustrates one piece of switchboard apparatus we left for description at this point, the rheostat. The reducing regulator and rheostat are both for the purpose of lessening the voltage when desired. They do this by compelling the current to flow through conductors

of different resistance. For example, you may lower the voltage of a current by compelling it to flow through wrought iron instead of copper, since wrought iron has a resistance six times as great as copper.

Because of this question of resistance, the home plant transmission lines leading from the power plant to the buildings to be supplied with current, should not be smaller than No. 8 copper wire, American, or Brown and Sharpe (B. & S.), wire gage. They should be covered with weather proof insulating. Indoors the wires should not be smaller than No. 14, copper wire, B. & S. gage, better No. 12 size, and still better No. 10 size, since the smaller numbered wires are the larger in diameter. The distance current is to be carried determines the size of wires. Wire for indoor use should be covered with rubber insulation. The larger the diameter of the wire, the less the resistance and the less the loss in current in transmission. In the back part of this book the B. & S. wire gage is reproduced in a table. The largest size is No. 0000, which is 0.46 of an inch in diameter. The smallest size is No. 36, which is 0.005 of an inch in diameter. The size of wire decreases by one-half with every three numbers, thus No. 7 wire is twice the diameter of No. 10 wire and No. 10 wire is twice the diameter of No. 13 wire.

A piece of No. 10 copper wire 1,000 feet long is said to have an electrical resistance of one ohm. The ohm, so called after one of the greatest names in electrical research, is the unit of resistance. Using the 1-ohm resistance of 1,000 feet of No. 10 copper wire as a base, the same size and length of wrought iron wire would have a resistance of 6 ohms. All substances vary in this property of resistance and glass and rubber have such tremendous resistance to current that they are used to insulate electrical carriers. Now a piece of copper wire twice the diameter of No. 10 wire will have just half the resistance. Thus the resistance of 1,000 feet of No. 10 copper wire is 1 ohm while the resistance of 1,000 feet of No. 7 wire is ½ ohm. Or, No. 13 wire, which is just half the diameter of No. 10 wire, has a resistance twice that of No. 10 wire. The smaller the wire the greater the resistance. This explanation mav be slightly tedious, but its importance warrants it.

The wires of the home electric plant should run in pairs, not singly. Each outlet that taps the current for light or power must be connected to the two wires. This is termed connecting in parallel or multiple. In cities we perhaps have noticed street lights that were connected to but one wire. This wire goes out from a plus or positive terminal and may run down one street and through a number of lights many blocks. Then it turns and comes back on another street, supplying more lights and finally ending at a minus or negative terminal on the switchboard of the power plant. This is called connecting in series. It saves on wire but it requires a voltage much too heavy and dangerous for use in the home or for a home plant. The resistance in series connecting is so great it requires a heavy voltage to overcome. For example, suppose we had ten incandescent lamps connected in series on a circuit and say the resistance of each lamp was 200 ohms. The total resistance would be 10 times 200 which would be 2,000 ohms, a load the home plant could not carry. But suppose we connected the ten lamps on two wires, one wire running from a positive terminal and the other running to a negative terminal on the switchboard of the plant. The total resistance in that case would be 200, the resistance of one lamp, divided by 10, the number of lamps, which would be 20 ohms, a very light load.

The reason for that lower resistance of connections in parallel can be demonstrated by referring back to the 1,000-foot length of No. 10 copper wire, which has a resistance of 1 ohm. Suppose we solder another 1,000-foot length of No. 10 copper wire to the first wire. The total length of the wire over which the current would travel would then be 2,000 feet and the resistance would be 2 ohms. But suppose we laid those two wires alongside each other and fastened them together at both ends. The current would travel then only 1,000 feet, but as the wires would be connected in parallel the resistance would be only ½ ohm. By connecting the wires in parallel we have doubled the size of the conductor and halved the resistance.

In wiring a building the wires may be carried in metal conduits, which is very desirable, but expensive. That method is not usual in home wiring, in which the pairs of wires usually are supported by split porcelain knobs or by porcelain cleats. The

split knobs require only one nail or screw to hold them and thus have an advantage over the cleats that require two nails or screws. The nails or screws of knobs should penetrate the wood they are attached to a distance at least half the length of the knob. Where wires penetrate walls, floors or wood they should be protected by porcelain tubing, small lengths of "crockery" made in the shape of a tube. Flexible circular loom is used where it is desired to insulate curved parts of the circuit and consequently the straight porcelain tubes could not be used. It is preferable to have wall switches in each room, but where expense is to be kept down to the minimum these switches may be eliminated and the current turned on or off by a key or a pull chain at the lamp socket. Pull chain sockets cost about twenty cents more than key sockets but are worth the difference where no switches are used, since they do not jar fine filament lamps as much as does the turning on or off of a key socket. At least have a pull chain socket for the bathroom light. Incandescent lamps out of doors should be controlled by an indoor switch and should have solid sockets that cannot be turned on or off. A pull chain socket is next best for out-of-doors lamps. In barns, particularly in long dairy barns, and other large buildings it is very desirable to connect the lamps in small circuits; that is, one switch controlling each circuit. Say one of these circuits has five lamps, then those five lamps may be turned on from that one switch while work is being done in that part of the barn and the rest of the building be left in darkness because no light is needed there. Where the wires enter a building a small double-pole knife switch, fuses and lightning arresters should be installed in a closed box.

Chores are the killing part, the great drawback to any country home. A home electric plant draws the teeth of this bugbear. There is no end to the good it works. Not only does it lighten household and farm work, but it makes life easier and more attractive. The bright lights that lure boys and girls to the city are electric lights. It is an established fact that the home with an electric plant can keep its sons and daughters more easily and has less trouble retaining competent help. Any farmhand will hesitate to leave a place equipped with electricity that makes his work lighter. If he is married, the electric lighted tenant house,

possibly supplied with water from a pump driven by the home water power plant, will so appeal to his wife that she won't let him quit except for a mighty good reason. It's easier and better to live where there is electricity. If you have ever fumbled for matches and the chimney of a smelly kerosene lamp when a child was sick at night you will realize that for that one reason alone, electric light when a member of the family is ill, the home electric plant is worth its price.

Electricity has been over-written frequently and for that reason we have hesitated to make claims for electric heating. Heating by electricity has not yet reached an advanced stage. It can be done successfully, but the cost is so high that the richest men would not attempt to heat their homes entirely by electricity. Coal, wood, oil or gas would be so much cheaper as heat sources that few persons would pay the big difference to heat with electricity, if they had to buy current at anything like the average price. However, the owner of a home water power electric plant can do it successfully and economically if he installs a large enough plant. With a small plant the current is required for light and other purposes and enough of it to furnish sufficient heat could not be spared, even if there was enough current alone for heating. However, a small electric heater in bathroom or bedroom to take the chill off is a practical convenience on slightly chilly days when the usual home fires are not burning.

Direct current generators and direct current motors may be used interchangeably, to produce or to use current. Because of that fact most of us have met and had experience with electric generators more often than we realize, only the generators were in the form of electric motors in electric fans and other machines. If then, the small electric fan motor, knocked about from year to year and receiving no more expert attention than the women of a household or the office boys or janitors of a business house can give it, continues to give years of useful service, how much more dependable and durable and self-sufficient should be the sturdier-built electric generator of the home power plant?

CHAPTER IX

Dams

DAMS are obstructions placed in streams solely to save water and to direct water into pipes or flumes and through the pipes or flumes to apply water to useful purpose, either power development or irrigation, or both. Whether a dam is a temporary thing of brush weighted down with stones, or a row of sand bags or a few flimsy boards nailed together, the same common sense principles apply to its use as to the great concrete, arched dam that may rear a hundred feet or more of slender height between the rock walls of a mountain gorge and hold back millions of tons of water to form a lake covering thousands of acres.

These principles of dam construction have been so well worked out in the last fifty to seventy-five years that any man who knows how to use a hammer and saw and the multiplication table can, with only this book as a guide, build a better dam and a cheaper dam than could any of the ancient kings who had the resources of kingdoms and workmen by the tens of thousands at their disposal. Solomon in all his glory could have built a prettier dam, undoubtedly, but he couldn't have built as safe a dam as can the man of today with an ax and with the pockets of his overalls filled with 16-penny spikes. Dams that are built right cannot possibly wash out.

Occasionally in the development of small water power plants it is not even necessary to build a dam at all. If there is enough water at the head of the riffle or rapids, where the dam naturally would be placed, to cover the intake of the pipe or flume that leads to the water wheel the water will follow the law of gravity down that pipe or flume and through the water wheel just as readily as it will obey the pull of gravity that sends it down the stream, dashing its force against the stones on its way down. This fact has been mentioned elsewhere in this book, but it cannot be too firmly imbedded in mind that a pipe or flume is only an artificial part of the

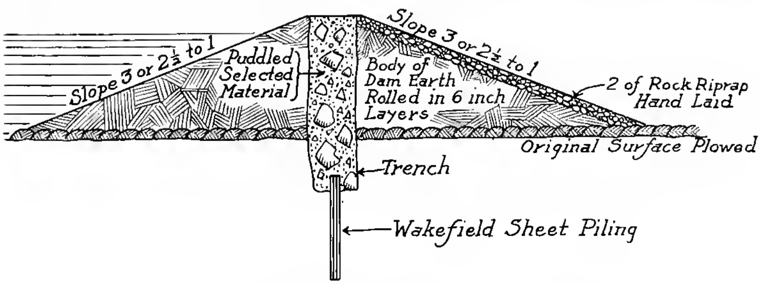
stream bed and that the stream bed itself is nature's flume or pipe. Usually, however, it is necessary to build a dam to direct the water into the intake or to get a higher fall of water than the stream naturally affords. To raise the water only a few inches or perhaps a foot or so in some small power developments temporary dams are used, consisting of sand bags placed across the stream, or of bundles of brush weighted or staked down, or of stones and a few boards. These, dams, of course, leak copiously and are washed out with every freshet, yet where only a tiny quantity of water is needed to be diverted to the water wheel they are sometimes practical because renewing them costs next to nothing.

These temporary dams may be tossed across a stream with half a thought. The permanent dam must be gone at in a workmanlike manner. It may be of earth, wood, stone, concrete or steel, or of some combination of two or more of these materials. If the dam is of earth, always it must be remembered that the water never can be allowed to flow over an earth dam. If it does flow over an earth dam, just as surely as water runs down hill that dam will wash out. Earth dams always must be provided with a spillway or channel of sufficient size to carry off all excess water. The spillway is placed near the top or crest of the dam, in the center or at either side. The spillway should be lined tightly with boards or concrete so that at no point does the running water come in contact with the earth of the dam as the water flows from the upstream side of the dam, through the spillway and down to the extreme downstream side of the dam. Earth will hold still water satisfactorily, but moving water will wear it away.

The picture on page 70 shows an earth dam and spillway. It will be noticed that this dam is very wide at the base and that both upstream and downstream the sides of the dam slope gradually to the crest. On the upstream side of this dam the slope or slant is determined by the fact that for each one foot in height of the dam on the upstream side the dam is three feet wide at the base. On the downstream side the dam is 2½ feet wide at the base to each one foot in height. Lest this description might be slightly confusing, please keep in mind that the width of a dam is the distance from the upstream side of the dam to the downstream side. The length of a dam is the distance from one bank of the stream to the opposite bank.

The crest of the dam may be just wide enough for a footpath, or by widening the base of the dam, it may be made to serve as a roadway across the stream, a bridge being placed across the spillway.

In building any kind of permanent dam, all mud, vegetable matter and loose material must be removed from the bed of the stream where the dam is to be placed. As most small streams

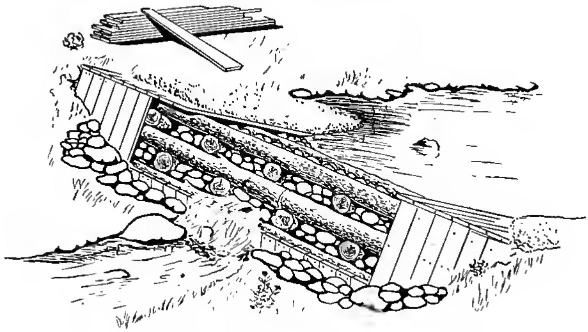


Earth Fill Dam with Cutoff Trench and Puddled Cove

usually cut their beds down close to bed rock or to hard clay or other stable formation, this part of the work is often very easy. The really difficult part in earth dam construction is in places where the dam rests on solid rock. It is hard to keep the water from seeping between the dam and the earth and finally undermining the dam. Perhaps as satisfactory a way as any is to blast and pick out a series of ditches in the rock, each ditch being about a foot deep and about two feet wide and being the same length as the base of the dam. Fill each of these small ditches with three or four inches of wet clay and puddle it by walking up and down the ditches or driving a horse up and down them. Add more layers of wet clay and repeat the puddling process until the dam is several inches higher than bedrock. The upstream half of the earth dam should be of clay or heavy clay soil, which puddles and is impervious to water. The downstream side of the dam should consist of lighter and more porous soil, which drains out quickly and thus makes the dam more stable than if it were entirely of clay. Sometimes satisfactory earth dams are only two feet at the base for each one foot in height, but the foregoing dimensions for earth dams have been made very generous purposely.

The kind of material cheapest to use and certain natural conditions of the dam site determine the type of dam to be employed.

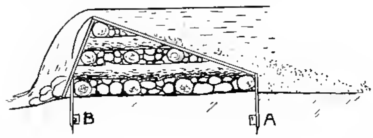
Earth dams are cumbersome and perhaps the least to be desired, although they can be adapted to their purpose with entire satisfaction. The universal dam is perhaps the crib dam, which consists of poles, rough and green if desired, or sawed lumber, criss-crossed on one another at intervals of two or three feet and spiked together. The spaces between the timbers are then filled with



stones and the upstream side or face of the dam is covered with planks to prevent the dam from leaking materially. The picture on this page shows a small crib dam, the view being from the downstream side of the dam. In this picture it will be noticed that the work of planking both the upstream face and the downstream face of the dam has been but partly finished and that the stream has found a way through the center of the dam. As soon as all the planks are nailed in place on the upper side and the upper face of the dam partly covered with clay, as is shown in the picture, the water will cease to flow through the dam and will have to rise sufficiently to flow over it. The planks are nailed on the downstream face of the dam, not so much to stop leaks as to direct the water falling over the crest of the dam and not permit a part of it to leak into the dam.

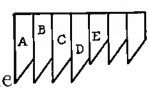
Look, please, a little more closely at this small picture. At the heel of the dam; that is, at the base of the dam on the downstream side, you will notice a row of planks driven into the stream bed. These are priming planks to prevent water seeping under the dam. See Fig. B. A similar row of priming planks is driven into the bed of the stream at the toe of the dam, Fig. A. The toe

of the dam is the base of the dam at its farthest upstream side. Of course, if the dam rests on rock, priming plank cannot and need not be driven, but where the dam does not rest on rock, priming



Cross Section of Small Crib Dam. A and B Indicate Priming Plank

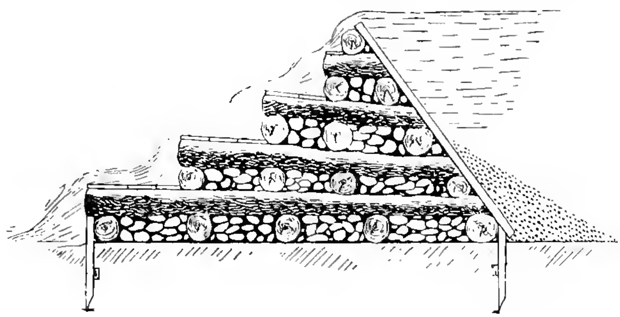
plank make the dam much more serviceable, more stable. Now water wheels use such a comparatively small quantity of the water available, in most instances of the smaller power developments, that priming plank may be objected to quite reasonably as an unnecessary detail, but priming plank, just the same, are a very workmanlike and sensible thing to have as a part of any dam not on bedrock.

Priming plank should be driven to "refusal," that is, as far as they can be driven, and then spiked to the crib dam. The lower end of the plank should be sharpened thus,  The plank should not be sharpened in the shape of a "V," thus  Priming plank should be driven in this order: Drive plank A first, then plank B and the other planks in alphabetical order, keeping the points of the planks as shown in the drawing herewith. 

The reason for this is that each successive plank is thus forced, by the mere act of driving the plank, closer up against the preceding plank. Any rough, sound lumber may serve for priming plank, altho chestnut and oak are recognized as excellent for these plank. Much care must be taken that the plank are free from sap. Two-by-sixes make excellent priming plank.

The picture on page 73 shows a cross section of a somewhat larger crib dam. You will notice that in this crib dam the upstream side of the dam is very steep, almost straight, while in the picture of the smaller crib dam the upstream face was almost flat. Either design is good. In the picture of the larger crib dam it will be noticed, too, that the downstream side of the dam, call it the apron of the dam, is in a series of stairsteps, to break the force of

the falling water gradually. In building this crib dam a row of green poles about four inches in diameter was placed across the stream at the toe of the dam; in fact, this first row of poles is the toe tip of the dam. If the stream is small, one pole or timber will reach across it. The poles or timbers used should be of varying



lengths so that there will be no joint or line of breakage any distance in the dam. Two and a half or three feet lower down in the stream bed another pole or several poles are laid. Now we have a number of poles laid across the stream in parallel rows. That is the first course of poles. The second course of poles is laid to crisscross the first course. The second course of poles is immediately on top of and spiked to the first course. The poles of the second course are laid two and a half or three feet apart in parallel rows and parallel to the banks of the stream. They run up and down stream. Their length is determined by the height of the dam, for, for each one foot in height the crib dam should be three feet wide at the base.

Now comes the third course of poles. It is laid on the second course to crisscross it and is spiked in place. The third course poles run from bank to bank, as do the poles of the first course, and the last row of third course poles on the downstream side is omitted. This is for the purpose of giving that stair-step effect to the apron of the dam. The fourth course is then laid, crisscrossing the third course of poles. It, of course, is shorter than the preceding second course, since one row of poles has been omitted from the third course. The process of laying successive crisscrossing poles is continued until the crib has reached the

desired height, the dam becoming narrower toward the top through the omitting of one row of poles in the successive across-stream courses and the shortening of the successive up-and-down-stream poles, to give the stair-step apron of the dam.

When the crib is finished the priming plank is driven at toe and heel, if the dam does not rest on rock, the crib is filled with stones, the upper face and the apron of the dam are sheeted with planks. Clay is dumped onto the upper face of the dam, or is omitted, leaving the dam to "silt up" and become more water tight through the water depositing sediment. The dam is finished.

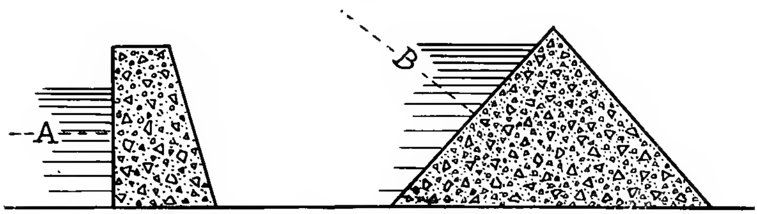
Where a dam is on bedrock, do not smooth the stone evenly. If the rock presents a somewhat level surface it is better to make that surface rough and uneven. If the surface is rough with depressions, ridges, and points jutting up, so much the better. This uneven condition braces the dam and prevents possible sliding. This holds for crib, concrete, and masonry dams.

Dams have gone out because they slid or overturned. And they slid or overturned because they were not built right to resist the pressure of the water and their own weight. Throughout the world there are here and there huge ruins, where kings or their underlings built failures that were to have been dams. They piled up huge mountains of great blocks of perfectly cut stone, laid with the precision of master workmen, and those master workmen were masters in every sense of the word, too. But their dams washed out. Those master workmen could build monuments of stone in temple and palace to shame the builders of even today, but they could not build dams. The two or three essential principles in successful dam building were not known to them. In fact scientific dam construction was very little developed until the French government took up the subject about seventy-five years ago. America and the whole world owes much to the French, for it was French engineers who took the first big important step in dam building and it was a Frenchman who first developed the turbine water wheel.

One reason those mountains of cut stones the kings set up as dams didn't succeed was because they were cut stone. Neither cut stone nor brick should be used in dam building. In masonry dams rubble should be used so that the stones of varying sizes make only irregular joints between the stones. Another reason

the kings didn't succeed was that their dams were too heavy. They crushed themselves. If they didn't crush themselves of their own weight, the added pressure of the water against them caused them to overturn or to collapse.

It isn't a matter of piling great quantities of material in a stream to dam it. It's largely a question of proportioning the dam. The pressure of the water against the face of the dam always exerts its force in a line perpendicular to the face of the dam.

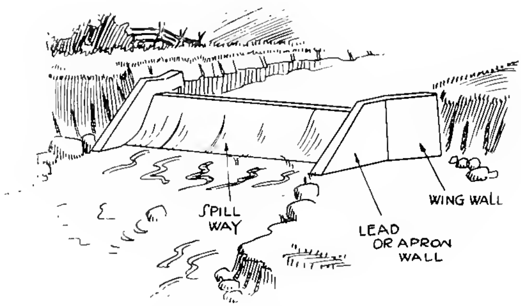


Water Exerts Pressure Perpendicularly Against The Face of the Dam. The Dotted A Shows How the Pressure Comes Against a Dam With a Vertical Face. The Dotted Line B Shows How Pressure Comes Against a Dam With a Slanting Face.

Thus if the dam face is vertical the pressure will be exerted along a horizontal line, A, as shown in the small drawing on left side of this page. If the face of the dam is slanting, as in the drawing shown on right side of this page, the water pressure is exerted perpendicularly to that face, or along the line B, as shown in the drawing. Obviously, if the dam with the vertical face is not built right the water is going to slide that dam down stream. Also, if the dam with the slanting face isn't built right the water is going to crush it or overturn it. For we must remember that in addition to the pressure of the water the dam must bear its own weight and the weight of the water flowing over it, and that somewhere along a line at the base of the dam these two great forces, pressure and weight, are going to converge in maximum lines of force. Engineers know the limits in which the resultant of the pressure and the weight forces will converge and they design dams to counteract this combination. That is why one dam with twice the material in it that another dam has, will not hold, while the lighter, small dam will hold.

Small masonry dams or concrete dams built without technical advice in small streams usually hold. The pressure is not sufficient

to harm them. But where the dam is of fair size, if of masonry or concrete, it should be designed by a dam expert. As these dams most usually require considerably less material in their construction than do the home-design dams, the buying of dam blue prints and specifications most often is a big saving. Not only is material and labor saved, but there is the comforting knowledge that the dam will last through generation after generation.



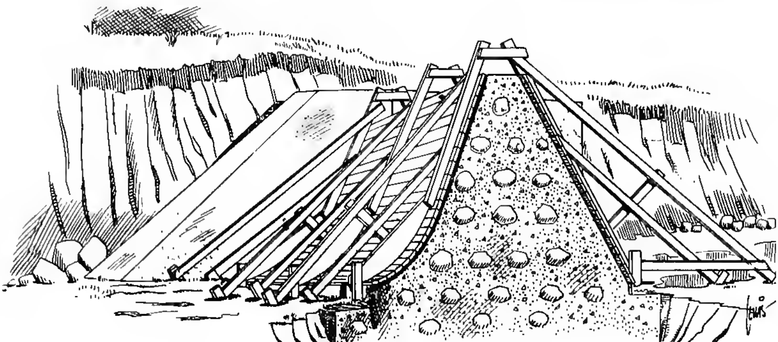
The picture on this page is a typical masonry dam for a small stream. Its base is 1.25 feet for each one foot in height. It is of uncut stones laid in Portland cement mortar.

Where the banks of the stream are solid rock, as in some of the notable dams in the great reclamation projects in the West and Southwest, the dam may be an arched dam, either of masonry or concrete. The dams we have been considering, up to this point, have been gravity dams, which are the general type of dam, the arch dams being used only in the greatest engineering works of reclamation, and where there is a natural, solid wall of bedrock on each side of the stream to take the thrust of the arch.

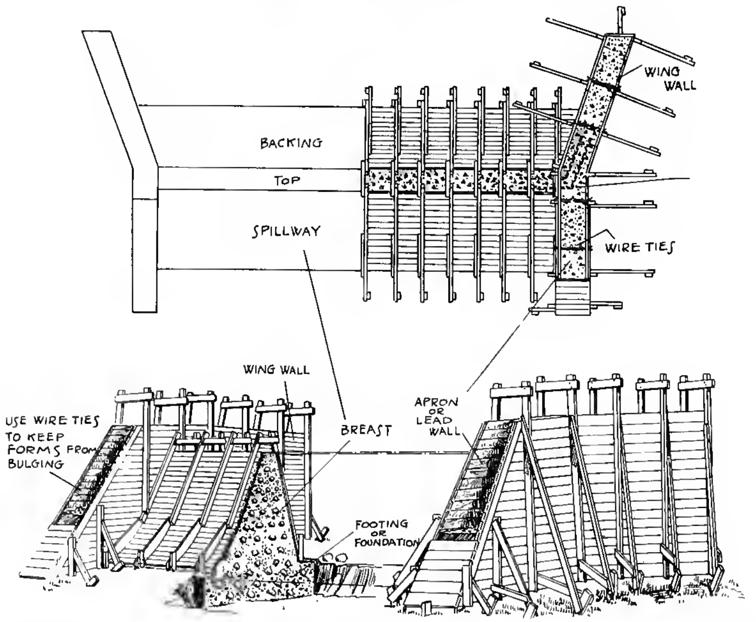
Since some of the readers of this book may have available a small stream flowing through a rocky gorge, arch dams are mentioned briefly here, although they should never be attempted unless designed by a competent engineer and, if feasible, supervised in construction by such authority.

An arch dam starts at the natural, solid rock wall on one side of the stream, curves gradually upstream to the center of the gorge or canyon and then curves downstream to the opposite wall. It is built solidly into the walls on either side. Remembering how

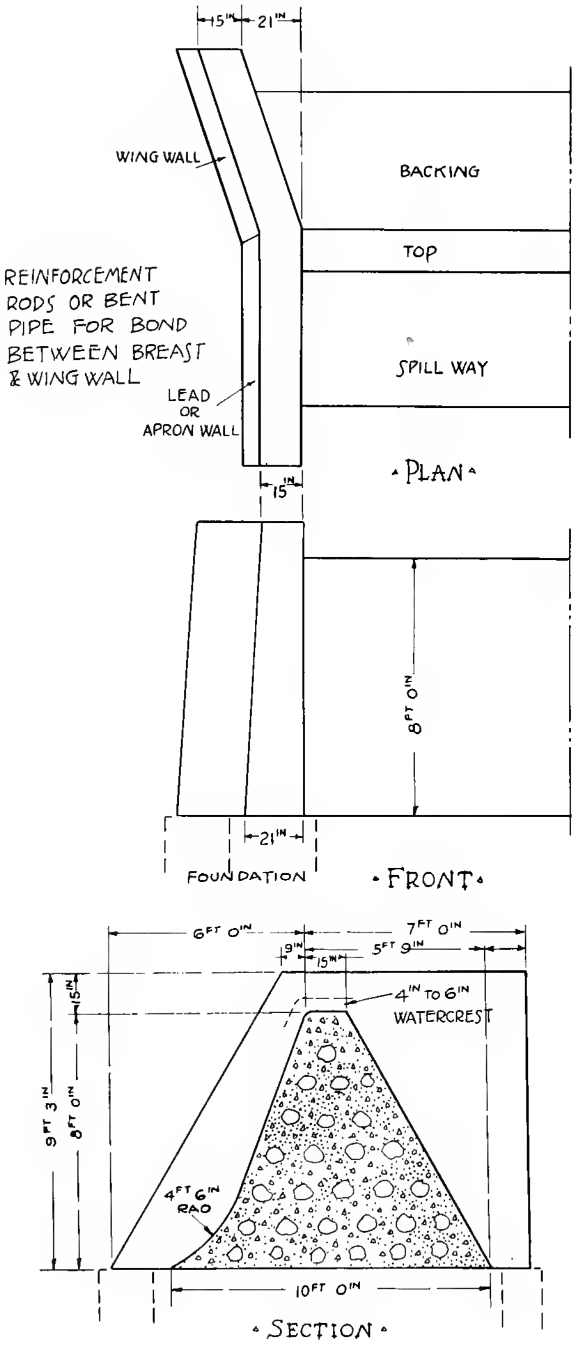
the arch of a stone bridge resists the weight put upon it, it is easy to appreciate how the slender, curved dam can successfully withstand the pressure of water upon it. At its base it usually has a



• SECTION OF BREAST SHOWING FORM BRACING •



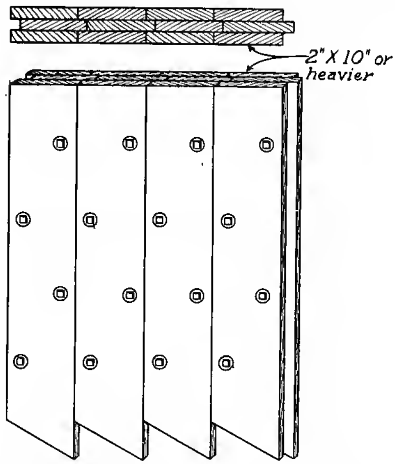
heel extending out a short distance, but throughout its whole makeup it is such a comparatively slender thing that were it built straight across the channel, instead of being curved it would collapse very quickly. Arch dams are used where great height is



15 IN
21 IN
WING WALL
BACKING
TOP
REINFORCEMENT RODS OR BENT PIPE FOR BOND BETWEEN BREAST & WING WALL
SPILL WAY
LEAD OR APRON WALL
15 IN
PLAN
8 FT 0 IN
21 IN
FOUNDATION
FRONT
6 FT 0 IN
7 FT 0 IN
9 IN
5 FT 9 IN
15 IN
15 IN
4 IN TO 6 IN WATERCREST
9 FT 3 IN
8 FT 0 IN
4 FT 6 IN RAD
10 FT 0 IN
SECTION

desired, as in irrigation projects that impound great lakes of water. Being curved, it reacts to the contraction and expansion as temperatures vary and does not crack. Sometimes the lower faces of these high dams, exposed to the full glare of the sun, are quite a few degrees warmer than the upper faces, covered by cool water.

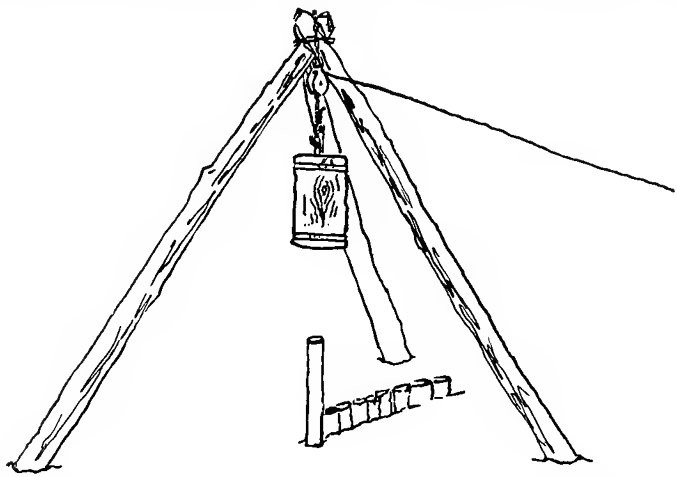
Arched and gravity dams sometimes are of masonry, but concrete is so much more easily handled and commonly is so much cheaper that the best permanent dams of today are largely of concrete. On pages 77 and 78 we give a complete design for a con-



Sheet Piling is Merely Priming Plank in Multiple Form. In this Use 2 x 10 Inch Boards are Cheaper than 2 x 6s, as There Should be a Certain Number of Bolts to each Board to Hold the Piling Together

crete dam eight feet high, ten feet wide at the base and fifteen inches wide at the crest. This dam is made of a mixture of 1 part best Portland cement, 2 parts sand, and 4 parts gravel, or coarse aggregate. Large stone may be used in this work, but care must be taken that they are clean and are entirely surrounded by the finer materials of the concrete. This dam is not to be used where the length of the dam must be more than fifty feet. It was designed for the Alpha Portland Cement Company of Easton, Pennsylvania. You will notice in Figure 1 of this dam design on page 77 that the downstream side of the dam is curved, which is for the purpose of throwing the escaping water outward and upward from the dam and preventing it from digging too great a hole

at the heel of the dam. This design is complete, except that priming plank are omitted. If the dam is not to be on rock, then this priming plank should be used and in place of a single thickness of priming plank, three thicknesses are preferable, being placed as Wakefield Sheet Piling with a waling strip on the outer side or on both sides. Two-by-sixes again are excellent for this use. The picture on page 79 shows such an arrangement of priming plank.



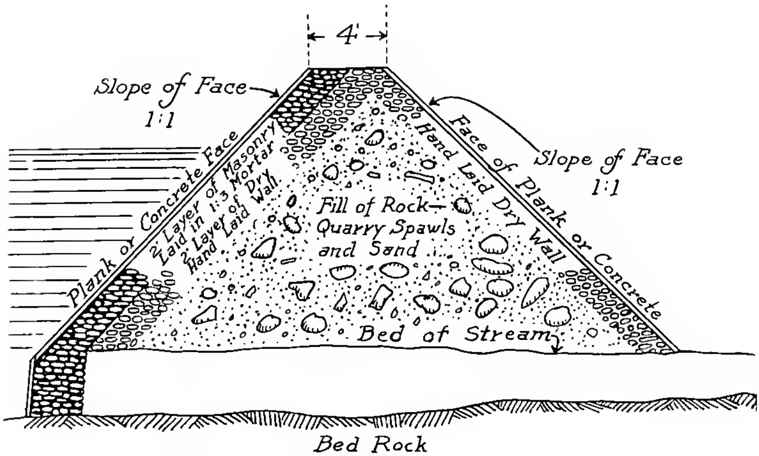
Note that the planks overlap so that joints do not come at any one place full through the thickness of the priming. In using such an arrangement of priming plank, it may be necessary to rig up a homemade pile driver. A log a foot or so in diameter and five or six feet long, fastened to a rope at one end will serve well. The picture on this page shows such a homemade pile driver.

A concrete or masonry dam more than 12 feet high should not be attempted without the advice of a competent engineer on the subject, first on the design and type of dam, and second on the footing the dam site offers. Now the stream bed may be of solid rock and may appear to any layman as absolutely safe to hold a dam. But, if, as it occasionally happens, this bedrock is porous, that little fact may threaten the stability of the dam with an unexpected force, the force of the water coming up underneath the dam through the pores of the rock. That condition undoubtedly would occur very, very rarely, almost never in fact, but we must

take into account all possibilities. We want our great-great-grandchildren to admire our dam and not to remark how careless great-great-grandfather was not to recognize the little fact about building solid dams on porous stone.

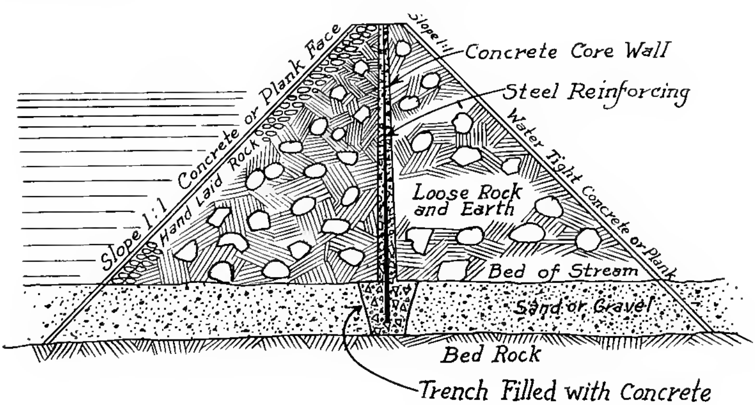
Further, if we put the solid dam on other than solid rock, there should be competent engineering authority as to whether that footing is sound enough. A soil-bearing test is a very wise precaution. It is a simple thing, sometimes made by digging a tiny hole into the area to be tested, setting a 12 x 12 timber in that hole and piling weights of iron or sand bags on a small platform on the upper end of the timber. In publishing this book we could easily have made the outlook of water power development so scarce of obstacles that it would seem a rose-garlanded pastime. The little chores and details such as priming plank, porous rock, soil-bearing tests, dumping in clay to "silt up" the dam could have been omitted and in 999 of a thousand dams their absence would not have been missed, but we feel that the interests of the thousandth developer of small stream water power should be considered always just as fully and particularly as those of the 999 water power users. The Rodney Hunt Machine Company has been making water wheels and devices for handling water for about fifty years. It hopes to continue improving and developing water power plants another fifty years. It can do so only by being wholly fair, by not only making good water wheels, pumps and other water machinery, but by making this book just as good.

While concrete dams often are the cheapest construction feasible, in some cases rock fill dams are the cheapest. The picture on page 82 shows a cross section of a rock fill dam. The rock fill dam is very similar to the earth dam, being a huge ridge of rock. It may be placed on porous rock or on practically any footing. The dam shown in the picture on page 82 has one foot in height for each one foot of width on the upstream side and one foot in height to each one foot in width on the downstream side. The upstream side of the dam is faced with rough rubble, set in cement mortar and a foot to two feet thick. This face of the dam is then covered with four to six inches of very rich concrete, the aggregate of the concrete being fine. The downstream face of the dam should be a dry wall about two feet thick. All the rest of the dam is of loose rock, just dumped in. The dam should have a spillway,



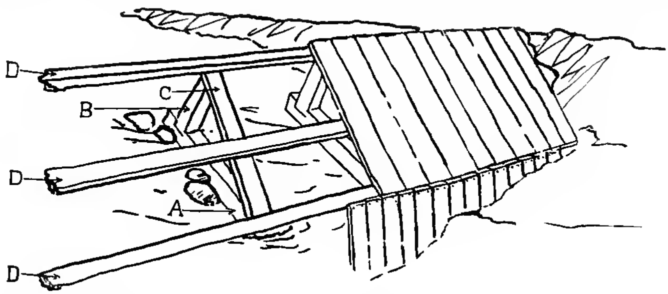
IN THIS PICTURE THE FACE OF THE DAM IS STRENGTHENED BY THE ADDITION OF THE DRY WALL BEHIND THE WALL LAID IN MORTAR. THIS DRY WALL MAY BE OMITTED, BUT AS ITS COST IS ONLY A LITTLE EXTRA LABOR IT IS GOOD PRACTICE TO INCLUDE IT

as in the earth dam, adequately lined with concrete or boards. If there is to be a small flow of water over the dam, then the crest and the downstream face must be sheeted with concrete or boards. Priming plank should be driven at the toe of the dam, if it is not on bedrock. The view shown below shows similar construction with center corewall a little more expensive but much more desirable form.



ROCK FILL DAM WITH CONCRETE CORE WALL

We have come now to the last type of dam we are to consider, the frame dam. It may be of wood, concrete, or steel, or a combination of materials. The drawing on this page is of a section of wooden frame dam. It shows a frame of heavy timbers supporting the face of the dam. The base timbers A in this dam are called



sills. The shorter timbers marked B are struts. The timbers marked C are rafters and the long timbers marked D are purlins. This design of dam as shown here may be built any length. As to height of dam, we give here dimensions for timbers for wooden frame dams of three different heights, four feet high, six feet high, and eight feet high. For a dam four feet high the sills should be 6 x 8-inch timbers ten feet long, the rafters should be 6 x 7-inch timbers eight feet long and the struts A should be 6 x 6-inch timbers five feet long. For a dam six feet high the sills should be 6 x 8-inch timbers fourteen feet long, the rafters should be 6 x 8-inch timbers twelve feet long and the struts A should be 6 x 6-inch timbers seven feet long. For a dam eight feet high the sills should be 6 x 8-inch timbers eighteen feet long, the rafters should be 6 x 8-inch timbers sixteen feet long and the struts A should be 6 x 6-inch timbers nine feet long. The sills should be no farther than six feet apart and the purlins no farther than four feet apart. The sills may be bolted fast to bedrock or to timbers running across the stream parallel to the purlins. The plank used for the facing should be at least two inches thick.

In any dam the end of the dam may be the weakest point in construction, for the water will try sometimes to eat around the ends of the dam by washing out the banks of the stream. For this reason the dam must be built well into the banks to prevent the

banks washing out, which is easily guarded against by reinforcing the face of the bank with a few loose stones or by driving in plank.

"But if I put in a dam it would back the water up fifty feet," some one remarks. "Would a dam, as described here, hold it?"

Certainly it would hold the water. It doesn't make any difference if you build a dam and back the water up ten miles or twenty miles, the same dam will hold it. Whether the pond or lake made by the dam is twenty miles long or any number of miles long makes no more difference than if the dam backs up only ten or twenty feet of water.

It is always well before building a dam to have the approval of local authorities, and before going ahead with larger dams it is best to consult an engineer.

CHAPTER X

Conduits

THE owner or owners of small water power plants for home, town or village betterment have a distinct advantage over the big, moneyed corporation that installs a great water power plant. The small plant can be arranged pretty much to suit the convenience of the owner, both in its method of construction and its location to natural surroundings. With the small plant the difference in cost between the ideal arrangement, recommended by a water power expert, and the possibly more convenient arrangement, decided on by the owner, is quite small both as to cost and the resulting efficiency.

But huge plants must follow somewhat rigid rules, whether convenient or not. The great volume of water they use is a colossal giant whose tremendous strength requires heavy harness. Consequently the big plants find it most advantageous to employ large water wheels under low heads of water, installing the wheels close up to the dam and eliminating long lengths of flume or penstock. ("Penstock" is only another word for "pipe.") On the other hand, the small plant can choose the more desirable arrangement of using a larger wheel under a low head close up to the dam. Or, it can use a smaller wheel situated some hundreds or thousands of feet from the dam, obtaining a higher head of water by carrying the water to the wheel in some form of conduit, flume, ditch or penstock. The smaller water giant employed by the small plant is so easily handled, the small water power plant owner can choose between the two arrangements without much difference in cost or efficiency.

However, it is an almost universal rule that placing larger wheels close to the dam, thereby utilizing a lower head of water and eliminating penstock and flume lengths as much as possible is the better arrangement. This statement is made in the face of the fact that the Rodney Hunt Machine Company has a complete line

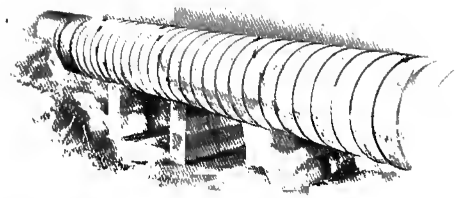
of wood and steel plate penstocks to sell, to meet any condition of water power development. The more of such materials it sells the better its business. Yet in sticking close to the purpose of this book, to give a truthful word picture of water power development, we advise against using long lengths of penstocks or flumes where it is at all practical to use a lower head of water and only a short length of penstock.

But some investigator into home or town water possibilities may say:

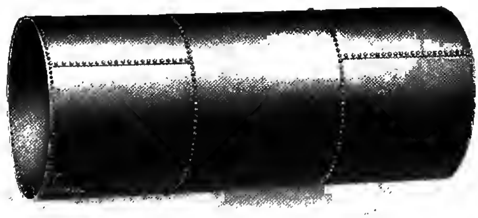
"The banks of our creek or brook are low. If we build a moderately high dam it is likely to cause overflows in flood times. Besides there is a week or two some years when the stream gets so low it might not have enough water to operate the larger wheel at full power. Besides, if we build a small dam it costs less than the larger dam and at the same time does not create a possible flood hazard. Now why can't we carry this water through a mill race or something to get a higher head of water? We can use a smaller wheel then, and as the smaller wheel takes less water the stream will always have enough water to run the wheel at full power. We'd get the same power from a small wheel and a little water under a high head that we would from a larger wheel under a lower head. What's wrong with using a mill race?"

Obviously there's nothing wrong with carrying the water a considerable distance through a conduit to the wheel, under such conditions. It is the best thing to do. The question comes down entirely to a choice of conduits, "conduit" being a general term in this case for pipes, penstocks, flumes, ditches and millraces. On page 87 is a picture of a wood stave penstock or pipe. It is one of the most satisfactory conduits yet devised. Its construction is just like that of a barrel, wooden staves held in place by iron bands, only the wood stave pipe has no bulge as has the barrel. Many advocates of wood stave pipe assert that it not only has greater durability and tightness, but that wood stave pipe or penstock will carry 10 per cent more water than either riveted or cast iron pipe. Wood stave pipe is practical for use under pressures up to 170 pounds to the square inch, or working under heads of water about 390 feet high. Under high pressures the staves are made thicker and the banding irons are

heavier and are placed closer together. Under moderate pressures the staves are thinner, the banding irons lighter and placed farther apart. Thus, if you bought a wood stave penstock for use under a moderate head of water, it would be built to suit that head of water and would not cost as much as the same diameter of pipe built for higher heads. The pipe is made of different kinds of wood to meet varying conditions and can be fitted with elbow or angle sections to permit the pipe to be curved in any direction that may be convenient or necessary. Added to its durability, lightness and ease of installation are two other prime qualities, cheapness, and capability of being repaired easily after long service. In addition to straight wood pipe the Rodney Hunt Machine Company furnishes curved wood pipe, hoops, bands, lugs, connectors for joining with steel pipe, cradle supports and all accessories and fittings.

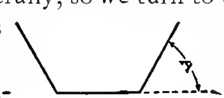


In some uses riveted steel plate penstocks are the best form of construction possible. The picture on page 88 shows a type of such construction. As with wood stave pipe, the steel plate pipe is made in different sizes and with plates of different thickness to work under different conditions and heads at the cheapest practical cost of installation. Connectors, reducers, and special shapes are also furnished when desired. In the earlier years of the Rodney Hunt business timber was universally used in the construction of water wheel flumes, pipes, and penstocks, and wheelwrights and carpenters were then an important part of our force. The lessening cost of steel has made possible the use of metal in many places where it may be more desirable than wood, and in 1897 we added to our works a plate and structural steel department which has grown rapidly and which is equipped with the best design of tools for accurate and careful work and for economic production of first class materials.



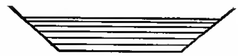
A circular conduit, either a wood or steel pipe, is the best form of conduit possible, because there is less wall space compared to the volume of water carried than in any other form of conduit. This minimum of wall space means a reduction in friction, and that more water can pass through the conduit in a given time than if the pipe were some other shape. A square penstock of the same cross section of a round pipe would not carry as much water as would the round pipe. Friction is a more important consideration than would seem possible perhaps to the man or woman unacquainted with the subject, and in the chapter in this book on centrifugal pumps we have emphasized, with the experiences of a Missouri farmer, the importance of considering friction in installing conduits. The Missouri farmer had to buy an extra size motor for his drainage plant solely because he neglected this item and put in a 4-inch discharge pipe instead of a 5-inch pipe. On page 163 you will find a pipe friction table showing how water is retarded at different velocities in different sizes of pipe through the friction of water against the pipe.

Friction in a flume or ditch demands just as much attention as in a penstock. As in a pipe we have seen that the round penstock has the least friction, so the flume or ditch in the shape of a half circle will have less friction and carry more water than in any other shape of equal area. In small conduits, sometimes used in fish hatcheries to carry water from one pond to another, half-tile pipes are used because they carry more water for the space they occupy than would the ordinary trough-like flume with straight sides. However, curved sides are not practical in flumes or ditches generally, so we turn to the next best shape of flume, a half hexagon thus



with the outside angle, A, between a side and the bottom being 60 degrees. Again, in excavations some soils will not hold a bank

as steep as this 60 degrees indicates. In that event the slant of the sides must be less. In any case the ditch with slanting, not straight, sides will pass more water than the straight-sided ditch of similar cross-section area. Now comes the question: Should I make my ditch with a wide bottom and gradually slanting sides, thus



Or, shall I have a narrow bottom and steeply slanting sides, thus

The water will be shallow and have a broad width in the broad bottom flume. It will be deep and narrow in the narrower bottom flume or ditch. The answer is to make the bottom as narrow and the sides as steep as possible up to 60 degrees. Or, stating a rule, next to a half-hexagon shape the best shape is one that with the depth of the water as the radius a circle drawn within the flume will touch the bottom and both sides, thus

The Rodney Hunt Machine Company will be pleased to advise you just what shape and size ditch to put in, if you propose to use a natural-bottom-and-sides ditch or a concrete-lined ditch as a conduit. This important principle of conduit construction was first discovered thousands of years ago by the world's first scientific builder, the honey bee, which divides its comb into hexagons because only in that form can it get the largest storage space for honey with a minimum quantity of wax for wall construction.

This hexagonal or trapezoidal cross section principle in flume construction applies almost entirely to ditches. It would be impractical and too expensive to build wood or concrete flumes on top of the ground with such shapes. The thing to do then is to build, on top of the ground, a flume with a straight, level bottom and straight sides, a rectangular flume. But even in this construction friction can be eliminated and more water carried by a proper relation of the height of the sides to the bottom. Thus, in the rectangular flume the normal depth of water should be half the width of the flume. Thus, the stream in a flume one foot deep should be two feet wide; or, if the water is three feet deep the flume should be six feet wide.

The picture on this page shows a concrete-lined ditch or flume. While it is desirable to line such ditches, it is not always necessary. This flume could be smaller if the slides were slanting, as explained

CONCRETE LINED FLUME
FROM LA HACIENDA, BUFFALO, N. Y.

in foregoing chapters, but there probably is enough water available that the friction element was not given thought and the extra cost of using more concrete to build a rectangular flume was not considered. The unlined ditch in a greater part of the farming areas of the Americas will hold water very satisfactorily after it has had a few weeks to "silt up." Where the ditch is in sandy soil and leaks considerably, put several inches of clay in the bottom of the ditch, wet it and then puddle it by driving horses or cattle up and down the ditch. The thickness of the concrete in lining such a flume depends entirely on the size of the flume. A drawback to unlined ditches is that in warm climates the ditches gradually fill up with vegetable growth that greatly obstructs the flow.

On this page is the picture of a wooden flume in course of construction. The picture on page 93 is a covered concrete flume. On pages 95-99 are designs for wood and metal flumes made

A Wood Flume in Course of Construction
FROM LA HACIENDA, BUFFALO, N. Y.

by the United States Reclamation Service, with tables of dimensions and quantities of materials.

The home owner, town or village official who has a water power prospect of any size can get from this chapter a fair idea of the conduit his particular water power development calls for. As a general thing flumes or penstocks are more satisfactory than mill races or ditches. The contour of the land, up-hill-and-down-hill, may make a ditch impossible. The ground may be too stony for economic excavation. Trees may interfere, being either in the direct path of the ditch or else breaking the bottom or sides of the ditch with their roots. Further, there may be objection to dis-

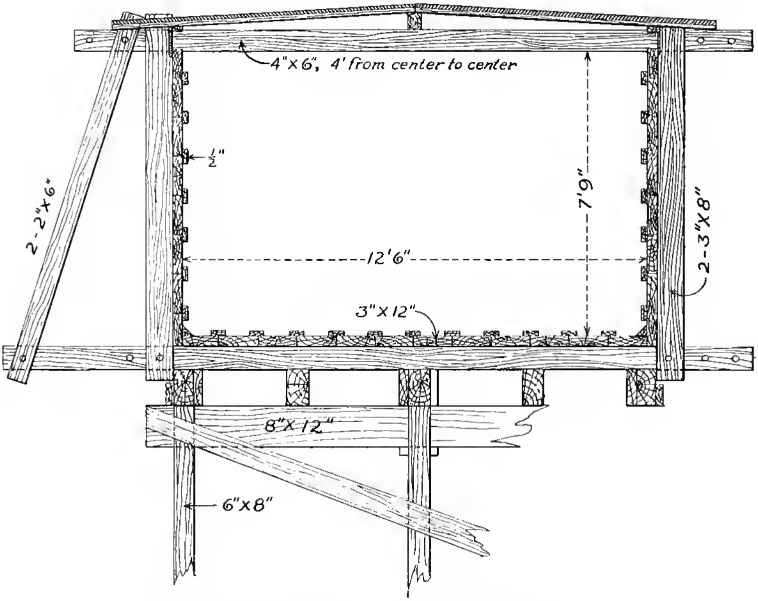
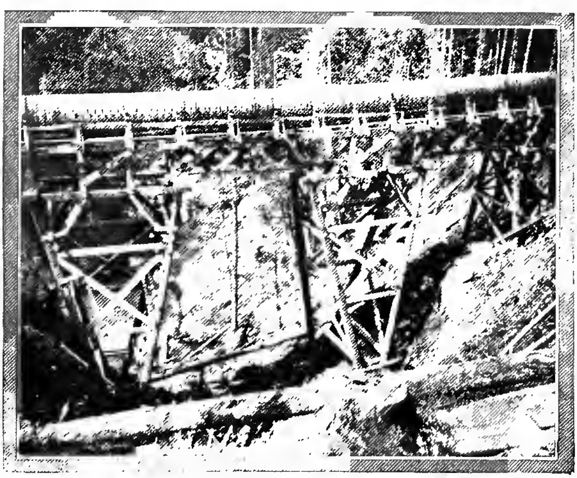


DIAGRAM OF CONSTRUCTION OF A COVERED WOOD FLUME
FROM LA HACIENDA, BUFFALO, N. Y.

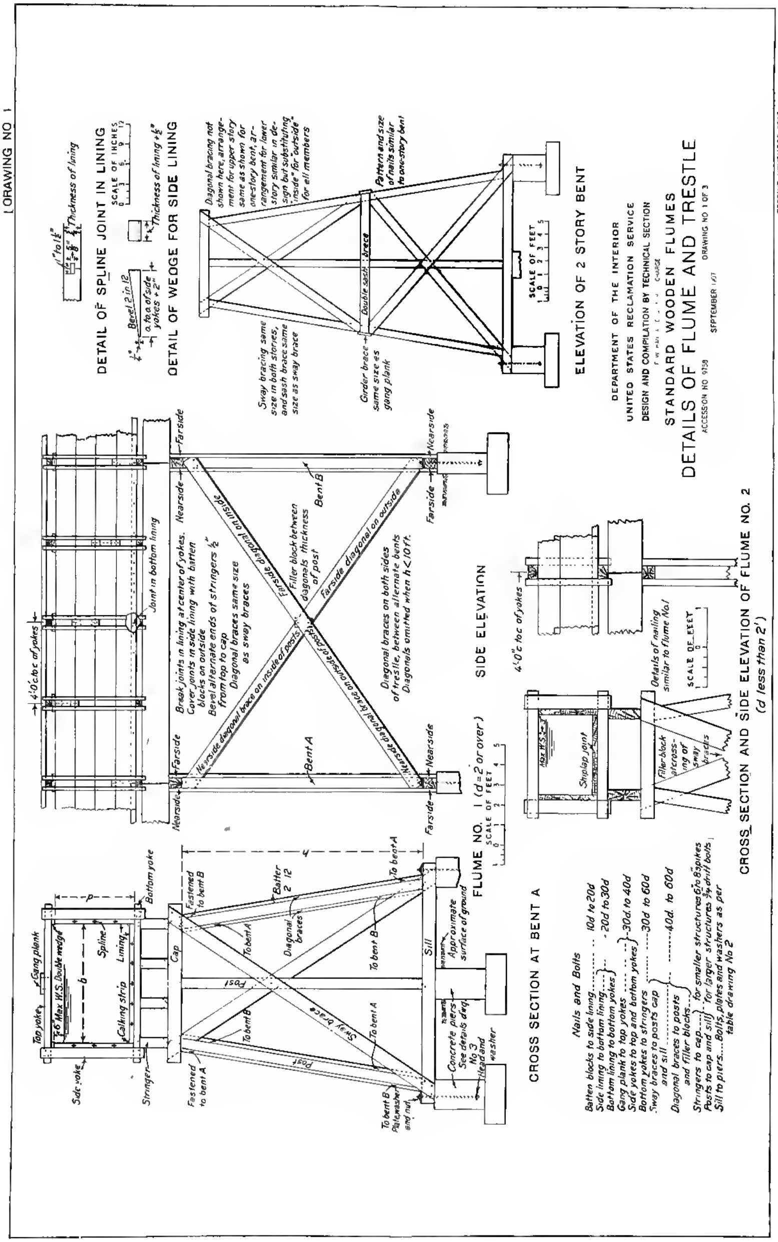
figuring a good bottom land field and breaking it up with a ditch. In this case a flume or penstock may follow along the edge of the bank with a minimum loss of arable land.



Covered Concrete Flume
FROM LA HACIENDA, BUFFALO, N. Y.

If the investigator of home, town or village water power plants will write to the Rodney Hunt Machine Company, Orange, Massachusetts, giving conditions under which he expects to develop water power, we shall be glad to advise him fully on all points of construction, including type, design, approximate costs, and sizes of different conduits applicable to his use. We retain a large

staff of trained men whose business it is to work out such information. We shall be glad to advise fully and accurately information on all points touching the development of any water power project. In writing for such information, please give details as fully as possible, stating the power that is expected to be developed, the fall of water available, flow of stream, nature of stream bed and surroundings. Different sizes and arrangements of water power plants can be specified very accurately and to conform to any pocketbook.


DRAWING NO 1
Top yoke
Gang plank
6" Max W.S. Double wedge
Side yoke
Spline
Calking strip
Lining
Stringer
Bottom yoke
Cap
Fastened to bent A
Fastened to bent B
To bent B
To bent A
Post
Batter 2 12
Diagonal braces
Sway brace
Sill
To bent B Platewasher and nut
Concrete piers See details dwg. No 3
Head and washer
Approximate surface of ground
CROSS SECTION AT BENT A
Nails and Bolts
Batten blocks to side lining .... 10d to 20d
Side lining to bottom lining ... Bottom lining to bottom yokes ... 20d to 30d
Gang plank to top yokes ... Side yokes to top and bottom yokes ... 30d to 40d
Bottom yokes to stringers ...... 30d to 60d
Sway braces to posts cap and sill ... Diagonal braces to posts and filler blocks ... 40d. to 60d
Stringers to cap ... for smaller structures 6" to 8" spikes
Posts to cap and sill ... for larger structures 3/4" drift bolts
Sill to piers.... Bolts, plates and washers as per table drawing No 2
4'-0" c to c of yokes
Joint in bottom lining
Nearside
Farside
Break joints in lining at center of yokes. Cover joints in side lining with batten blocks on outside
Bevel alternate ends of stringers 1/2" from top to cap
Diagonal braces same size as sway braces
Nearside diagonal brace on inside of posts
Farside diagonal on inside
Filler block between diagonals thickness of post
Nearside diagonal brace on outside of posts
Farside diagonal on outside
Bent A
Bent B
Diagonal braces on both sides of trestle, between alternate bents Diagonals omitted when h < 10 ft.
FLUME NO. 1 (d = 2' or over)
SCALE OF FEET
SIDE ELEVATION
Max W.S.
Shiplap joint
Filler block at crossing of sway braces
Details of nailing similar to flume No. 1
SCALE OF FEET
CROSS SECTION AND SIDE ELEVATION OF FLUME NO. 2 (d less than 2')
DETAIL OF SPLINE JOINT IN LINING
SCALE OF INCHES
Thickness of lining
Bevel 2 in 12
o. to o. of side yokes + 2"
Thickness of lining + 1/8"
DETAIL OF WEDGE FOR SIDE LINING
Sway bracing same size in both stories, and sash brace same size as sway brace
Diagonal bracing not shown here, arrangement for upper story same as shown for one-story bent, arrangement for lower story similar in design but substituting "inside" for "outside" for all members
Girder brace same size as gang plank
Double sash brace
Pattern and size of nails similar to one-story bent
SCALE OF FEET
ELEVATION OF 2 STORY BENT
DEPARTMENT OF THE INTERIOR
UNITED STATES RECLAMATION SERVICE
DESIGN AND COMPILATION BY TECHNICAL SECTION
STANDARD WOODEN FLUMES
DETAILS OF FLUME AND TRESTLE
ACCESSION NO 9758
DRAWING NO 1 OF 3
REPRINT NOVEMBER 1916

Number	d×b = height of flume × inside width, feet	Span in feet	Flume: Thickness of lining, inches	Flume: Dimensions of side yokes, inches	Flume: Dimensions of top and bottom yokes, inches	Flume: Stringers: Number	Flume: Stringers: Dimensions in ins.: Class A	Flume: Stringers: Dimensions in ins.: Class B	Flume: Stringers: Dimensions in ins.: Class C	Flume: Material: Lumber in ft B M: Class A	Flume: Material: Lumber in ft B M: Class B	Flume: Material: Lumber in ft B M: Class C	Flume: Material: Nails in lbs	Bents: Dimensions of caps and sills, inches	Bents: Number and size of posts, inches	Bents: Maximum height, feet	Bents: Height 10 ft: Dimensions of bracing inches	Bents: Height 10 ft: Lumber in ft B M	Bents: Height 10 ft: Nails in lbs	Bents: Height 10 ft: Anchor bolts: Diameter inches	Bents: Height 10 ft: Anchor bolts: Weight lbs	Bents: Max. height: Dimensions of bracing, inches	Bents: Max. height: Lumber in ft B M.	Bents: Max. height: Nails in lbs	Bents: Max. height: Anchor bolts: Diameter, inches	Bents: Max. height: Anchor bolts: Weight, lbs	Type of concrete piers see drawing No. 3
1	1×1	12	1½	1-4×2	4×2	2	2×8	2×6	2×6	110	110	110	8	4×4	2-4×4	10	2×6	100	8	5/8	10	2×6	100	8	5/8	10	1
2	1×1	16	1½	1-4×2	4×2	2	3×8	2×8	2×8	170	150	150	10	4×4	2-4×4	10	2×6	110	8	5/8	10	2×6	110	8	5/8	10	1
3	1×2	12	1½	1-4×2	4×2	2	3×8	2×8	2×8	150	140	140	8	4×4	2-4×4	10	2×6	100	8	1/2	8	2×6	100	8	1/2	8	1
4	1×2	16	1½	1-4×2	4×2	2	3×10	3×10	3×8	220	220	200	10	4×4	2-4×4	10	2×6	110	8	1/2	8	2×6	110	8	1/2	8	1
5	1×3	12	1½	1-4×2	4×2	3	3×8	2×8	2×8	200	180	180	10	4×4	2-4×4	10	2×6	110	8	1/2	8	2×6	110	8	1/2	8	1
6	1×3	16	1½	1-4×2	4×2	3	3×10	3×10	3×8	290	290	270	12	4×6	2-4×4	10	2×6	120	8	1/2	8	2×6	120	8	1/2	8	1
7	1½×2	12	1½	1-2×4	4×3	2	3×10	3×8	3×8	190	170	170	9	4×4	2-4×4	10	2×6	100	8	5/8	10	2×6	100	8	5/8	10	1
8	1½×2	16	1½	1-2×4	4×3	2	3×12	4×10	3×10	270	270	240	11	4×4	2-4×4	10	2×6	110	8	5/8	10	2×6	110	8	5/8	10	1
9	1½×3	12	1½	1-2×4	4×3	3	3×10	3×8	3×8	250	240	240	11	4×6	2-4×4	10	2×6	110	8	5/8	10	2×6	110	8	5/8	10	1
10	1½×3	16	1½	1-2×4	4×3	3	4×10	4×10	3×10	370	370	330	13	4×6	2-4×4	10	2×6	120	8	5/8	10	2×6	120	8	5/8	10	1
11	1½×4	12	1½	1-2×4	4×3	3	3×10	3×10	3×8	280	280	260	11	4×6	2-4×4	10	2×6	120	8	1/2	8	2×6	120	8	1/2	8	1
12	1½×4	16	1½	1-2×4	4×3	3	4×12	4×10	4×10	440	400	390	13	4×8	2-4×4	10	2×6	140	8	1/2	8	2×6	140	8	1/2	8	1
13	2×2	12	2	1-2×4	4×3	2	4×10	3×10	3×10	300	280	280	11	4×4	2-4×4	10	2×6	100	8	3/4	15	2×6	100	8	3/4	15	1
14	2×2	16	2	1-2×4	4×3	2	5×12	4×12	4×12	450	420	420	13	4×4	2-4×4	10	2×6	110	8	3/4	15	2×6	110	8	3/4	15	1
15	2×3	12	2	1-2×4	4×3	3	4×10	3×10	3×10	380	350	350	13	4×6	2-4×4	10	2×6	110	8	5/8	10	2×6	110	8	5/8	10	1
16	2×3	16	2	1-2×4	4×3	3	4×12	4×12	4×10	530	530	500	15	4×6	2-4×4	10	2×6	120	8	5/8	10	2×6	120	8	5/8	10	1
17	2×4	12	2	1-2×4	4×3	3	3×12	4×10	3×10	400	410	380	13	4×4	3-4×4	10	2×6	120	8	5/8	10	2×6	120	8	5/8	10	1
18	2×4	16	2	1-2×4	4×3	3	4×14	5×12	4×12	610	610	570	15	4×4	3-4×4	10	2×6	130	8	5/8	10	2×6	130	8	5/8	10	1
19	2×5	12	2	1-2×4	4×3	3	4×12	3×12	4×10	460	430	430	13	4×4	3-4×4	10	2×8	150	8	1/2	8	2×8	150	8	1/2	8	1
20	2×5	16	2	1-2×4	4×3	3	5×14	5×12	5×12	700	660	660	16	4×4	3-4×4	10	2×8	160	8	1/2	8	2×8	160	8	1/2	8	1
21	3×3	12	2	2-2×4	4×4	3	4×12	4×10	4×10	480	460	460	18	4×8	2-4×4	10	2×6	130	8	7/8	25	2×6	130	8	7/8	25	2
22	3×3	16	2	2-2×4	4×4	3	6×12	5×12	4×12	730	680	630	22	6×6	2-6×6	15	2×6	160	9	7/8	25	3×6	250	10	7/8	25	2
23	3×4	12	2	2-2×4	4×4	3	5×12	4×12	3×12	550	510	480	18	6×6	3-6×6	15	2×6	200	9	3/4	17	3×6	300	10	7/8	25	2
24	3×4	16	2	2-2×4	4×4	3	6×14	6×12	5×12	820	770	720	22	6×6	3-6×6	15	2×6	200	9	3/4	17	3×6	310	10	7/8	25	2
25	3×5	12	2	2-2×4	4×4	4	4×12	3×12	4×10	600	560	560	21	6×6	3-6×6	15	2×8	220	9	5/8	12	3×8	350	10	3/4	17	2
26	3×5	16	2	2-2×4	4×4	4	5×14	6×12	5×12	910	910	850	25	6×6	3-6×6	15	2×8	230	9	5/8	12	3×8	360	10	3/4	17	2
27	3×6	12	2	2-2×4	4×4	4	5×12	4×12	3×12	680	630	580	22	6×6	3-6×6	15	2×8	250	9	5/8	12	3×8	360	10	3/4	17	2
28	3×6	16	2	2-2×4	4×4	4	6×14	5×14	6×12	1020	950	950	26	6×8	3-6×6	15	2×8	260	9	5/8	12	3×8	390	10	3/4	17	2
29	4×4	12	2½	2-2×6	4×4	3	6×12	5×12	4×12	750	710	680	20	6×6	3-6×6	15	2×6	200	9	7/8	25	3×6	300	10	1	32	3
30	4×4	16	2½	2-2×6	4×4	3	6×16	6×14	5×14	1080	1040	980	24	6×6	3-6×6	15	2×6	210	9	7/8	25	3×6	310	10	1	32	3
31	4×5	12	2½	2-2×6	4×4	4	5×12	4×12	4×12	820	770	770	23	6×6	3-6×6	15	2×8	230	9	3/4	17	3×8	350	10	7/8	25	3
32	4×5	16	2½	2-2×6	4×4	4	5×16	6×14	6×12	1200	1200	1150	27	6×8	3-6×6	15	2×8	250	9	3/4	17	3×8	380	10	7/8	25	3
33	4×6	12	2½	2-2×6	4×4	4	6×12	5×12	4×12	910	860	810	23	6×8	3-6×6	15	2×8	260	9	3/4	17	3×8	380	10	7/8	25	3
34	4×6	16	2½	2-2×6	4×4	4	6×16	5×16	5×14	1320	1240	1190	27	6×8	3-6×6	15	2×8	270	9	3/4	17	3×8	390	10	7/8	25	3
35	4×7	12	2½	2-2×6	4×4	5	6×12	5×12	4×12	1030	970	910	26	6×8	3-6×6	15	2×8	270	9	5/8	12	3×8	390	10	3/4	17	3
36	4×7	16	2½	2-2×6	4×4	5	6×16	6×14	5×14	1510	1430	1340	30	6×10	[illegible]	15	2×8	310	9	5/8	12	3×8	440	10	3/4	17	3
37	4×8	12	2½	2-2×6	4×4	5	5×14	5×12	4×12	1050	1000	950	26	6×10	3-6×6	15	3×10	370	9	5/8	12	3×10	470	10	3/4	17	3
38	4×8	16	2½	2-2×6	4×4	5	5×18	5×16	6×14	1520	1470	1470	30	8×10	3-8×8	20	3×10	500	9	5/8	12	3×10	760	10	3/4	17	3
39	5×5	12	2½	2-3×6	4×6	4	6×12	5×12	4×12	1010	960	910	26	6×8	3-6×6	15	2×8	240	9	1	32	3×8	370	10	1	32	4
40	5×5	16	2½	2-3×6	4×6	4	5×18	5×16	6×14	1410	1370	1370	30	6×8	3-6×6	15	2×8	250	9	1	32	3×8	380	10	1	32	4
41	5×6	12	2½	2-3×6	4×6	4	6×14	6×12	5×12	1100	1050	1000	26	6×8	3-6×6	15	2×8	250	9	7/8	25	3×8	380	10	1	32	4
42	5×6	16	2½	2-3×6	4×6	4	6×18	6×16	5×16	1570	1500	1420	30	8×8	3-8×8	20	2×8	360	9	7/8	25	3×8	650	10	1	32	4
43	5×7	12	2½	2-3×6	4×6	5	5×14	6×12	5×12	1170	1170	1110	30	6×8	[illegible]	15	2×8	280	10	3/4	17	3×8	390	10	7/8	25	4
44	5×7	16	2½	2-3×6	4×6	5	6×18	6×16	6×14	1780	1700	1620	35	8×8	3-8×8	20	2×8	370	10	3/4	17	3×8	660	12	7/8	25	4
45	5×8	12	2½	2-3×6	4×6	6	5×14	5×12	4×12	1280	1230	1150	33	8×10	3-8×8	20	3×10	470	10	5/8	12	3×10	750	12	7/8	25	4
46	5×8	16	2½	2-3×6	4×6	6	5×18	5×16	6×14	1860	1800	1800	38	8×10	3-8×8	20	3×10	500	10	5/8	12	3×10	760	12	7/8	25	4
47	5×9	12	2½	2-3×6	4×6	6	6×14	4×14	5×12	1410	1260	1260	33	8×10	3-8×8	20	3×10	500	10	5/8	12	3×10	770	12	7/8	25	4
48	5×9	16	2½	2-3×6	4×6	6	6×18	5×18	5×16	2040	1900	1820	39	8×12	[illegible]	20	3×10	570	10	5/8	12	3×10	840	12	7/8	25	4
49	5×10	12	2½	2-3×6	4×6	7	5×14	4×14	5×12	1450	1370	1370	37	8×10	3-8×8	20	3×10	520	10	5/8	12	3×10	780	12	3/4	17	4
50	5×10	16	2½	2-3×6	4×6	7	6×18	6×16	5×16	2270	2150	2000	42	8×12	[illegible]	20	3×10	590	10	5/8	12	3×10	860	12	3/4	17	4

NOTE

Three kinds of lumber have been assumed, classified as follows:
Class A: Nominal unit stress 800
Class B: Nominal unit stress 1000
Class C: Nominal unit stress 1200
Flume lining, yokes and posts have been considered for each class A.
Stringers have been considered for each class.
Caps and sills have been considered only for class C.

Quantities in tahle are for one flume span and one bent and include no allowance for culls, waste, etc.

Anchor bolts shall be imbedded in concrete piers about 24 inches and provided with washers at imbedded end and plates on sills as follows:

Dia. Bolt	Dia. Washer	Size of Plate
1/2"	2"	4" x 4" x 3/8"
5/8"	2"	4" x 4" x 3/8"
3/4"	3"	4" x 6" x 3/8"
7/8"	3"	6" x 6" x 3/8"
1"	4"	6" x 7" x 3/8"

Department of the Interior United States Reclamation Service
Design and Compilation by Technical Section
F. W. Hanna, Engineer in Charge

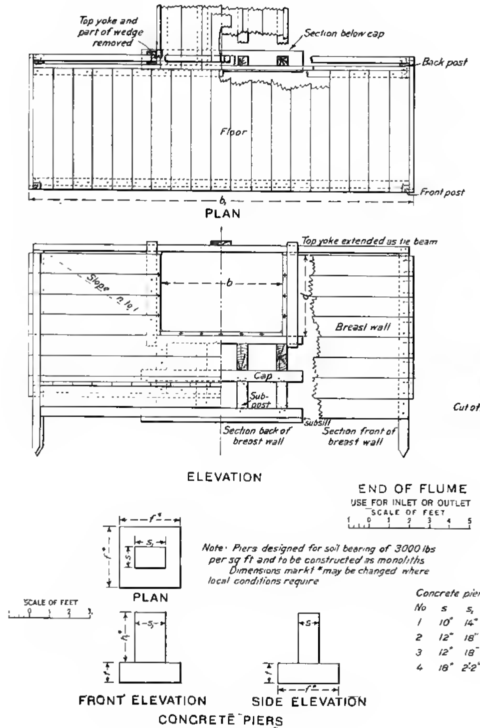
STANDARD WOODEN FLUMES
Dimensions and Quantities
Flume and Trestle Bents

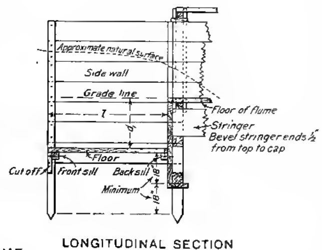
Accession No. 9760

Drawing No. 2 of 3

September 1907

DRAWING NO. 3





Lumber

Floor, breast and side walls and sub-sill, same as flume lining.
Sills and front posts, same as flume top and bottom yokes.
Cap, sub-posts, and back posts, same as trestle posts, 12 ft span.

Nails

Sub-posts to cap and sub-sill } *Front sill to front posts* } .... *6" spikes*
Back sill and tie beam to back posts. 8" spikes
Lining .... *20d to 40d*

Minimum Dimensions

(May be increast where local conditions require)

d_1 = 18" for d < 3 ft l = 3'-0" for d < 3 ft
= 24" " d = 3 "
= 2'-6" " d = 4 " } l = 1½d for d = 3 ft or more
= 3'-0" " d = 5 "
b_1 (for slope = n to 1) = b + 2nd + l

Quantities in one end

Size of flume d × b	Lumber in ft B.M	Nails in lbs
1×1	140	8
1×2	150	8
1×3	170	8
1½×2	190	10
1½×3	210	10
1½×4	240	10
2×2	290	12
2×3	310	12
2×4	340	12
2×5	360	15
3×3	540	15
3×4	610	15
3×5	640	15
3×6	680	15
4×4	1050	15
4×5	1090	20
4×6	1130	20
4×7	1170	20
4×8	1210	20
5×5	1530	20
5×6	1590	20
5×7	1640	25
5×8	1810	25
5×9	1870	25
5×10	1930	25

Note Quantities given in table include no allowance for culls, waste etc.

Concrete piers – Dimensions and Quantities

No	s	s_1	t	f	h	Cuyds in 3 piers
1	10"	14"	6"	20"	24"	0.5
2	12"	18"	9"	2'-6"	2'-6"	0.9
3	12"	18"	12"	3'-0"	2'-6"	1.5
4	18"	2'-2"	12"	3'-6	3'-0"	2.4

DEPARTMENT OF THE INTERIOR
UNITED STATES RECLAMATION SERVICE
DESIGN AND COMPILATION BY TECHNICAL SECTION

STANDARD WOODEN FLUMES

DETAILS OF END AND TRESTLE BASES

ACCESSION NO 9759 — DRAWING NO 3 OF 3
SEPTEMBER 1907

REPRINT NOVEMBER 1910

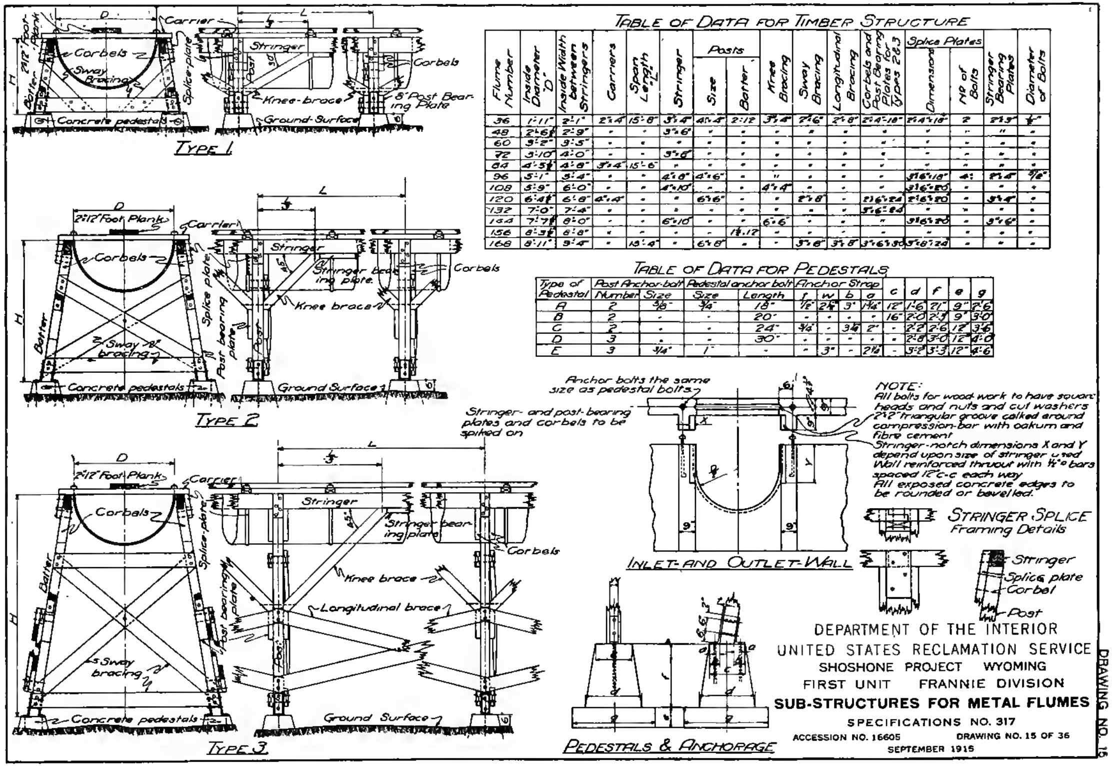


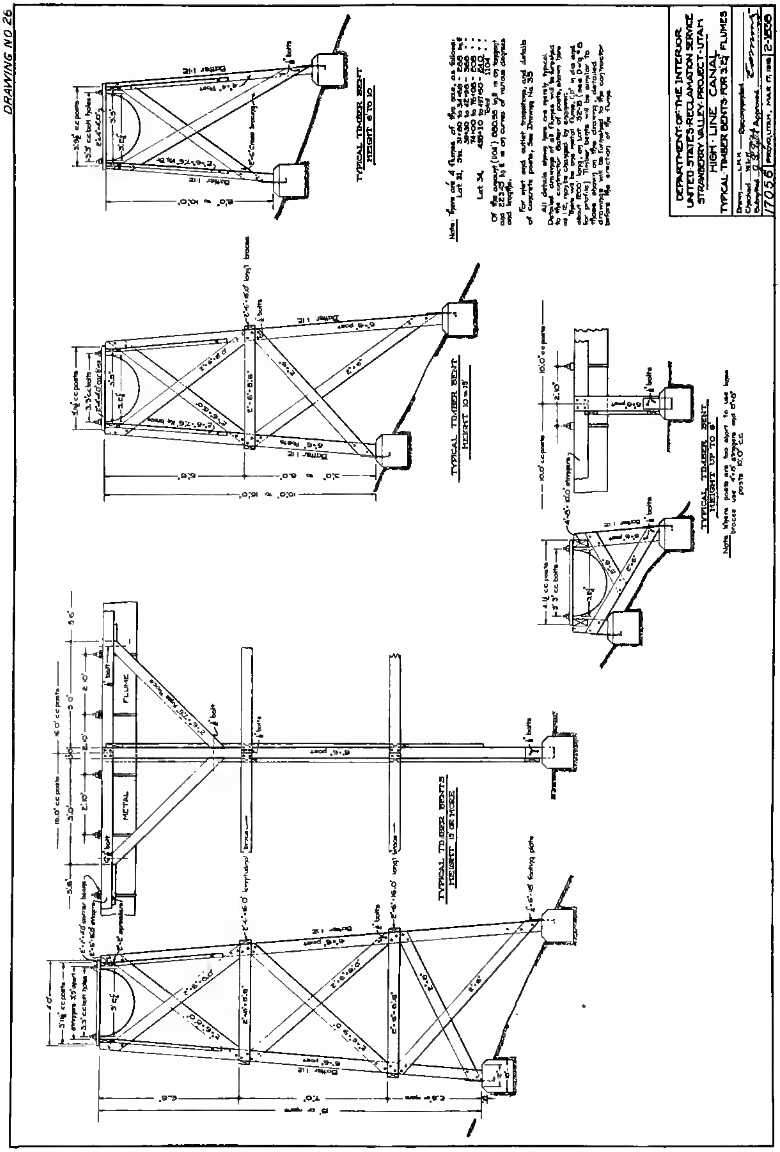
TABLE OF DATA FOR TIMBER STRUCTURE

Flume Number	Inside Diameter "D"	Inside Width between Stringers	Carriers	Span Length "L"	Stringer	Posts: Size	Posts: Batter	Knee Bracing	Sway Bracing	Longitudinal Bracing	Corbels and Post Bearing Plates for Types 2 & 3	Splice Plates: Dimensions	Splice Plates: No. of Bolts	Stringer Bearing Plates	Diameter of Bolts
36	1'-11"	2'-1"	2"x4"	15'-8"	3"x4"	4"x4"	2:12	3"x4"	2"x6"	2"x8"	2"x4"-18"	2"x4"x18"	2	2"x3"	½"
48	2'-6½"	2'-9"	·	·	3"x6"	·	·	·	·	·	·	·	"	"	·
60	3'-2"	3'-5"	·	·	·	·	·	·	·	·	·	·	·	·	·
72	3'-10"	4'-0"	·	·	3"x8"	·	·	·	·	·	·	·	·	·	·
84	4'-5½"	4'-8"	3"x4"	15'-6"	·	·	·	·	·	·	·	·	·	·	·
96	5'-1"	5'-4"	·	·	4"x8"	4"x6"	·	"	·	·	·	3"x6"x18"	4	2"x4"	5/8"
108	5'-9"	6'-0"	·	·	4"x10"	·	·	4"x4"	·	·	·	3"x6"x20"	·	·	·
120	6'-4½"	6'-8"	4"x4"	·	·	6"x6"	·	·	2"x8"	·	2"x6"x24"	2"x6"x20"	·	3"x4"	·
132	7'-0"	7'-4"	·	·	·	·	·	·	·	·	3"x6"x24"	·	·	·	·
144	7'-7½"	8'-0"	·	·	6"x10"	·	·	6"x6"	·	·	"	3"x6"x20"	·	3"x6"	·
156	8'-3½"	8'-8"	·	·	·	·	1½:12	·	·	·	·	·	·	·	·
168	8'-11"	9'-4"	·	13'-4"	·	6"x8"	·	·	3"x6"	3"x8"	3"x6"x30"	3"x8"x24"	·	·	·

TABLE OF DATA FOR PEDESTALS

Type of Pedestal	Post Anchor-bolt: Number	Post Anchor-bolt: Size	Pedestal anchor bolt: Size	Pedestal anchor bolt: Length	Anchor Strap: f	Anchor Strap: w	Anchor Strap: b	Anchor Strap: a	c	d	f	e	g
A	2	5/8"	3/4"	18"	½"	2½"	3"	1¼"	12"	1'-6	2'-1"	9"	2'-6
B	2	·	·	20"	·	·	·	·	16"	2'-0	2'-3	9"	3'-0
C	2	·	·	24"	3/4"	·	3½	2"	·	2'-2	2'-6	12"	3'-6
D	3	·	·	30"	·	·	·	·	·	2'-8	3'-0	12"	4'-0
E	3	3/4"	1"	·	·	3"	·	2½	·	3'-2	3'-3	12"	4'-6

DRAWING NO 26



CHAPTER XI

Home Uses of Concrete

THE concrete catechism reads, "One part best Portland cement, 2 parts clean, coarse sand, 4 parts crushed stone or gravel," with monotonous regularity. For different strengths and uses of concrete the catechism occasionally changes to include three other proportions, 1 part cement, 1½ parts sand, and 3 parts stone, or 1 part cement, 2½ parts sand and 5 parts stone, or 1 part cement, 3 parts sand, and 6 parts stone. Those four mixtures are the standardized dependable proportions that comprise the law of general, every-day use of concrete. That law should be changed to read:

"Concrete for general home use should consist of 1 part best Portland cement and such proportions of sand and gravel as are cheapest and handiest and at the same time fit into the purpose for which the concrete is to be used."

This is another way of saying that the man who makes concrete should take advantage of the more abundant native material he has at hand and not follow blindly the catechism of concrete. If, as happens very frequently, there is a supply of native gravel to be had for the taking, it is practical to increase the proportion of stone somewhat and cut down the quantity of sand, if the sand has to be bought and hauled from a distant point and is, therefore, an expensive part of the job. This substituting of stone for a small part of sand may effect a great saving in dam, road, retaining wall and other heavy construction. In such heavy construction very large stones may be used successfully; in fact, in the great Elephant Butte Dam "plums" weighing several tons have been made a part of the concrete. This chapter, in dealing with the more general uses of concrete on the farm, does not seek to give specific directions that will fit every case where saving could be effected by changing from the old, standard mixtures. That would be impossible. But a careful reading of this chapter should indicate

pretty clearly how such general principle in saving may be applied in particular instances.

Concrete is artificial stone, made by binding or cementing fast together sand and stone. The principle of its formation is that any box or measure filled with gravel or crushed stone will contain comparatively large air spaces. Sand then is added to fill up these air spaces, and though enough sand and stone are packed into the box to appear to fill it solid, there still is a multitude of small air spaces in the mixture of sand and stone. The purpose of the cement is to fill all these small air spaces and at the same time to bind sand and stone together in a solid mass. In speaking of these three materials used in concrete making, the sand usually is called the fine aggregate and the stone or gravel is called the coarse aggregate.

Good sand for concrete should consist of hard, durable grains ranging from 1-32nd of an inch in diameter for the smallest and ¼ of an inch in diameter for the largest. The sand should be evenly graded from the smallest to the largest grains, so that the smaller grains fill in the voids between the larger grains. The finer the sand the weaker the concrete and the more cement required. While as much as 5 per cent of the concrete may be finely divided clay, without injuring the concrete, the sand must be free of all dirt, loam, humus or other vegetable matter. Sand should look clean to be clean. If it has a dead appearance it is dirty and should not be used without washing. When dry, clean sand will not lump. If lumps appear when the sand is dry they are caused by the grains being "cemented" together with dirt. Pick up a handful of moist (not dry) sand and work the fingers of that hand over it several times as it is squeezed in the palm. If the fingers or palm are stained or dirty the sand is unfit for use until washed. To wash the sand, use a screen of thirty meshes to the inch, fastening the screen to the underside of a wooden frame and preventing the screen from sagging or breaking by nailing cleats across the bottom of the frame. Elevate one end of the screen until the screen is at an angle of about 30 degrees. The sand is shoveled onto the upper end of the screen and is gradually washed down to the lower end of the screen by water being sluiced over it with a hose or buckets. A screen six feet or longer should be used.

The coarse aggregate consists of particles of hard, clean stone ¼ of an inch diameter, as the smallest, up to the huge "plums" weighing tons and used in mass construction. As a general thing, however, the coarse aggregate does not run more than 2½ inches in diameter. Above that size care must be taken to tamp the concrete extra well so that there are no voids, which are more likely where large particles of coarse aggregate are used. In reinforced concrete work coarse aggregate larger than 1 inch in diameter should not be used. The reason is that larger stones are likely to make voids along the reinforcing steel and thus prevent the finer materials from binding the reinforcing and the concrete in a solid mass. The coarse aggregate, too, should be evenly graded from the finest to the coarsest, so that the finer particles of stone fit in among the larger stones, just as the finer sand acts to fill spaces between the larger grains of sand. The coarse aggregate should be any hard stone, such as granite, flint, hard limestone. Sandstone is not so good. Usually it is too soft, although it sometimes is used in important work, as in locks recently built on the Ohio River. The coarse aggregate must be clean and free from dirt. If dirty it should be washed over a ¼-inch screen, as the sand was washed.

The water used in concrete making should be good, clean water, free of strong alkalis. Sea water should not be used.

The standard mixture of concrete for general purposes is 1-2-4; that is, 1 part cement, 2 parts sand, and 4 parts stone. This mixture is suitable for the best wall construction, for dams, columns, fence posts, tanks, silos, conduits, arches, cisterns, and practically all work requiring especially strong concrete. To waterproof cisterns, dams, walls, and tanks, 5 to 10 per cent of hydrated slaked lime may be added to the concrete; that is, the quantity of lime may be 5 to 10 per cent of the quantity of the cement. To illustrate, a batch of concrete calls, we'll say, for two bags of cement. Cement weighs ninety-four pounds net to the bag. We'll take out about fifteen pounds of cement and substitute fifteen pounds of lime. This, however, must be remembered as the only instance in which we will measure by weight. All other measurements herein in making concrete are by volume. To use more than 10 per cent lime, as directed here, will weaken the con-

crete. In waterproofing, the presence of the lime in the concrete reacts to the carbonates that are in most waters and causes deposits of them to fill up the minute pores of the concrete. Never use quick lime in connection with concrete. It must be thoroughly slaked.

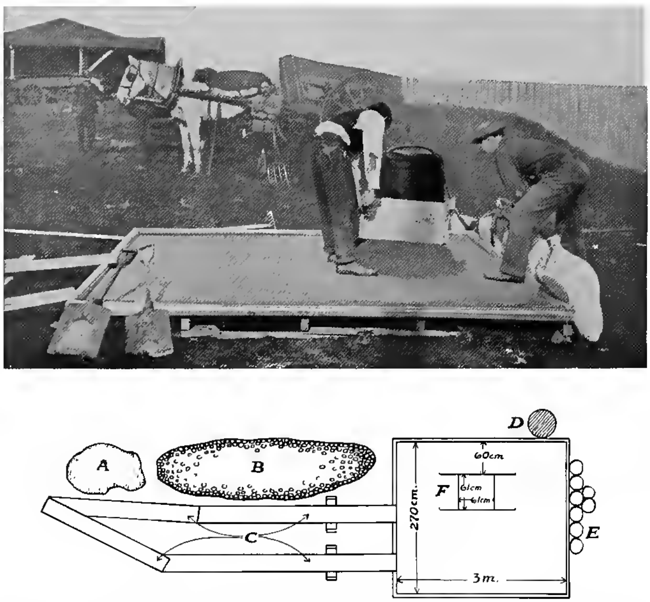
Where columns require a particularly strong structure the concrete may be 1-1$\frac{1}{2}$-3 in proportions. Foundations, cellar walls, sidewalks, cellar and barn floors are often of 1-2$\frac{1}{2}$-5 mixture. Dams, too, sometimes are found to be entirely adequate when made of this mixture. Piers for supporting buildings such as corn cribs, barns, shops, water wheels, and the like may be of a lean mixture 1-3-6.

For maximum strength of concrete only enough water should be used to wet up the cement chemically, which will give the fresh mass of concrete a plastic, slightly quaking consistency. The addition of more water reduces the strength of the concrete, just as surely as would taking away some of the cement. However, to facilitate handling of concrete it often is wet sufficiently to make it flow sluggishly, thus sacrificing a bit of the strength that is not essential usually to the success of the work. Sloppy mixtures, though, should never be used. Be as sparing as possible with water. Concrete failure very often is because of too much water. Fluidity of mixture should be obtained by thorough mixing, for good mixing is a very important part of the process.

"In this description, and the accompanying illustrations, we have taken as a basis a 'half-barrel batch' of 1-2-4 concrete.

"First load your sand in wheelbarrows from the sand pile, wheel it onto the 'board,' and fill the sand measuring box, which is placed about 60 cm (approximately 2 feet) from one side of the board, as shown by the diagram in Fig. 1. When the measuring box is filled, lift it off and spread the sand over the board in a layer 8 or 10 cm. (about 3 or 4 inches) thick, as shown in Fig. 2. Take the two bags or half-barrel of cement and place the contents as evenly as possible over the sand (see Fig. 2). With the two men at the points marked "x" and "xx" on the sketch below Fig. 2, start mixing the sand and cement, each man turning over the half on his side of the line ZZ. Starting at his feet and shoveling away from him, each man takes a full shovelload, turning the shovel over

at the points marked 1 and 2 respectively in Fig. 2. In turning the shovel, do not simply dump the sand and cement at the points marked 1 and 2 in the diagram under the cut, but shake the materials off the end and sides of the shovel, so that the sand and

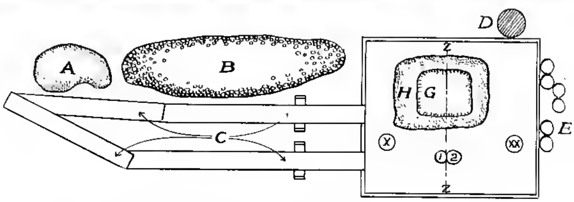


A Sand. B Stone. C Walks. D Barrel for water. E Cement.
FIG. 1. LIFTING THE CASE TO MEASURE THE SAND TO MIX THE CEMENT

cement are mixed as they fall. This is a great assistance in mixing these materials. In this way the material is shoveled from one side of the board to the other, as shown in Figs. 3 and 4. Figure 3 shows the first turning, and Fig. 4 the second turning.

"The sand and cement should now be well mixed and ready for the sand and water. After the last turning, spread the sand and cement out carefully, place the gravel or stone measuring box beside it as shown in Fig. 5, and fill from the gravel pile. Lift off the box and shovel the gravel on top of the sand and cement, spreading it as evenly as possible. With some experience equally good results can be obtained by placing the gravel measuring box on top of the carefully leveled sand and cement mixture, and filling

it, thus placing the gravel on top without an extra shoveling. This method is shown in Fig. 6. Add about three-fourths the required amount of water, using a bucket and dashing the water over the gravel on top as evenly as possible. (See Fig. 7.) Be

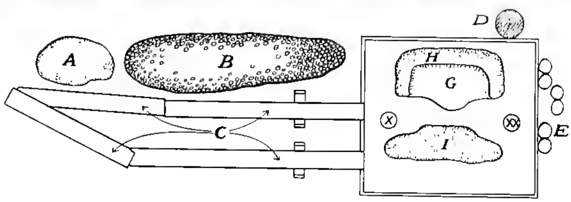


A Sand. B Stone. C Walks. D Barrel for water. E Cement. G Cement. H Sand.

FIG. 2. SPREADING THE CEMENT ON THE SAND

careful not to let too much water get near the edge of the pile, as it will run off, taking some of the cement with it. This caution, however, does not apply to a properly constructed mixing board, as the cement and water cannot get away. Starting the same as with the sand and cement, turn the materials off the end of the shovel, the whole shovel load is dumped as at points 1 or 2 in the diagram under Fig. 2 and dragged back toward the mixer with the square point of the shovel. This mixes the gravel with the sand and cement, the wet gravel picking up the sand and cement as it rolls over when dragged back by the shovel. (See Fig. 8.) Add water to the dry spots as the mixing goes on until all the required

water has been used. Turn the mass back again, as was done with the sand and cement. With experienced laborers, the concrete should be well mixed after three such turnings; but if it shows streaky or dry spots, it must be turned again. After the

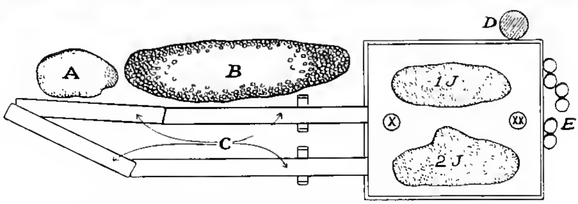


A Sand. B Stone. C Walks. D Barrel for water.
E Cement. G Cement. H Sand. I Sand and Cement mixed.
FIG. 3. FIRST TURN OVER SAND AND CEMENT

final turning, shovel into a compact pile. The concrete is now ready for placing."

The mixing of concrete should be more than mixing. It should be kneading and working the mass as well. For this reason mechanical mixers are more satisfactory on larger jobs. Select a mixer that kneads as well as stirs the concrete, one that has an arrangement of buckets inside the drum whereby the material is lifted well toward the top of the drum before it drops the material as the wheel revolves. This type mixer is more satisfactory than the mixer having only vanes in the drum or mixing chamber. There should be no recesses in the mixer where concrete may lodge, set up and require a chisel to be removed.

When a mechanical mixer is used, the concrete should be mixed in the mixer at least one minute. The speed of the mixer should be between ten and sixteen revolutions per minute.



A Sand. B Stone. C Walks. D Barrel for water.
E Cement. J Sand and Cement.

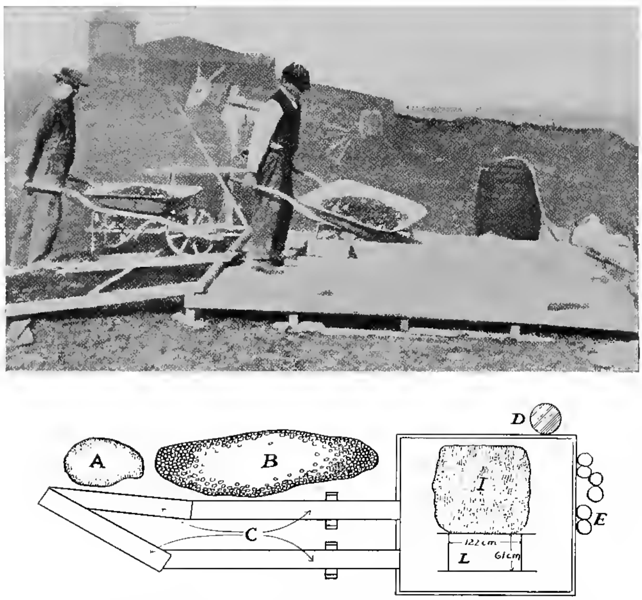
FIG. 4. SECOND TURN OVER SAND AND CEMENT

The mixer should be strongly built to withstand hard usage by unskilled men.

Mixers usually are equipped with a skip, which receives the materials. First the sand is put in, then the cement and then the wet stone or gravel. The skip then dumps into the mixer and a workman adds the water by means of a hose. In mixing concrete by hand only buckets should be used to add the water. The coarse aggregate should be wet before being mixed. Also, wherever cement mortar is used in masonry, the stone should be wet first.

Never mix concrete on the ground if avoidable. Use a board or platform, preferably of tongued and grooved material, with a

small edge two or three inches higher than the board, nailed at the edges to prevent material from being washed off. The board may be any size big enough for men to work on. A board eight or ten



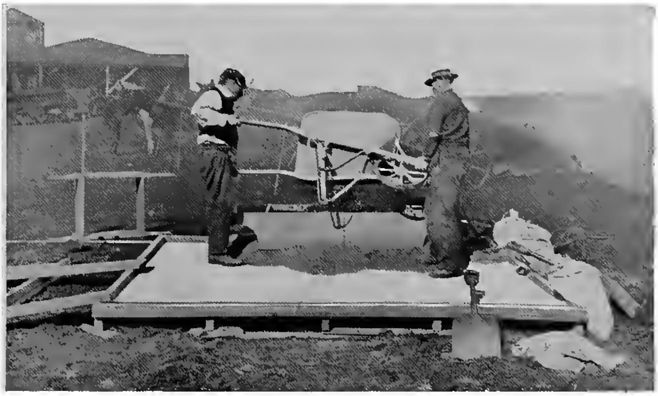
A Sand. B Stone. C Walks. D Barrel for Water. E Cement. I Sand and Cement mixed. L Box for Measuring Stone.

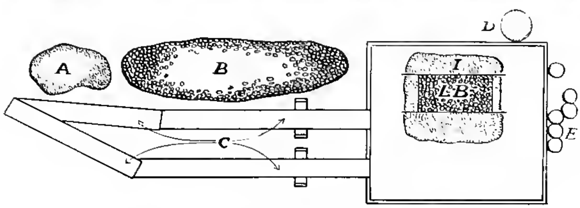
Fig. 5. Filling the Box to Measure the Gravel (first method)

feet square is about an average size. The concrete materials may be measured in a wheelbarrow or other receptacle, but a more accurate way is to use a measuring box, which is a frame without top or bottom and with handles for lifting it projecting at each end. The size of these boxes varies with the mixtures to be used. Taking a 2-bag batch, that is a batch requiring two bags of cement, the 1-1½-3 mixture requires a box 3 by 2 feet and 10 inches deep, inside dimensions. The 1-2-4 mixture requires a box of the same depth but 4 feet long and 2 feet, 4 inches wide. The 1-2½-5 mixture requires a box a foot deep, 4½ feet long, and 2 feet, 2 inches wide while 1-3-6 mixture requires a box the same depth

and length but two feet 7 inches wide. One box, however, can be adapted to all uses with a little figuring.

A quick direction for mixing concrete by hand is to spread out the sand, add the cement, then turn three or four times,





A Sand. B Stone. C Walks. D Barrel for water.
E Cement. I Sand and Cement mixed. LB Stone.

FIG. 6. FILLING THE BOX FOR MEASURING THE GRAVEL WHICH IS SURROUNDED BY THE SAND AND CEMENT MIXED (second method)

shoveling from you and until the color of sand and cement mixture show they are well mixed. Then add wet stone and shovel, turning the mixture over, three times or more before adding the water. Concrete should be placed as soon as mixed. For this reason only small batches should be mixed at a time. Concrete may be mixed during freezing weather provided the ingredients are heated and the concrete after it is placed is prevented from freezing until it has set by covering it with at least fifteen inches of hay, straw, sawdust or some other available suitable material. Never use manure, it may discolor the concrete and it is very apt to cause the surface of the concrete to disintegrate. If a

concrete job must be left over night unfinished, as frequently is the case, it is excellent practice the next morning to scrape off the unfinished surface and cover it with a thick cream mixture of cement

FIG. 7. POURING THE WATER OVER GRAVEL WHICH IS ON TOP OF SAND AND CEMENT MIXTURE

about one-quarter of an inch thick before dumping on the fresh concrete. On floors, sidewalks and other exposed surfaces of concrete, wet down the surfaces daily while the concrete is setting, for, if one part dries rapidly and another slowly the concrete is weakened.

Do not make the natural mistake of supposing that a gravel bank is fixed by Nature as a sort of natural concrete and that, therefore, the gravel bank has the coarse aggregate all ready for use. Instead, screen the material taken from the gravel bank so that an evenly graded lot of gravel, from one-quarter inch particles to gradually larger particles is obtained and the finer stuff and possibly too large a quantity of the larger gravels eliminated. Excellent coarse aggregate is found in the tailings from mine mills. This aggregate usually runs about 1/4 to 3/4 inches in diameter. Quarry screenings are good for use in concrete if they are clean, but usually they are so dusty that they cannot be used with good results. Cinders and slag should not be used in concrete, except for the sub-base in such work as sidewalks and barn or cellar floors.

The only really essential rules for forms for concrete are that the forms be tight and that they be braced and fastened just tight

enough to hold the concrete without leaking until the mass hardens. Making forms over-strong necessitates more work and hammering in removing the forms and the less hammering and jarring about

FIG. 8. MIXING THE GRAVEL WITH THE SAND AND CEMENT

green concrete the better. Carpenters who regularly build and tear down concrete forms frequently do not drive nails home, so that the nails may be pulled more readily when the forms are taken down. Green lumber is excellent for concrete forms, for the same reason that lath often are allowed to remain in a damp place in lumber yards. Not being seasoned and dried out they are not likely to warp and pull away when put next to a wet mixture of concrete or mortar. The forms should be smooth for smooth-finish work, of course. To facilitate removal, or as in the case of an iron rod used to leave a hole in a concrete fence post, the form or parts of the form are greased.

In making a cistern the 1-2-4 mixture of concrete three or four inches thick should be used with 5 to 10 per cent of slaked lime putty being used in place of a like quantity of the cement. The bottom of the cistern should be at least six inches thick and for the outside of the cistern the earth walls of the excavation may be used for the outside of the form. To obtain the greatest water storing space, the cistern should be $1\frac{1}{2}$ times as deep as wide. The old jug-top cistern was wasteful of space and material. It is better to build the walls straight up, capping with an 8-inch thick

slab of concrete that is reinforced with heavy woven wire or with iron rods.

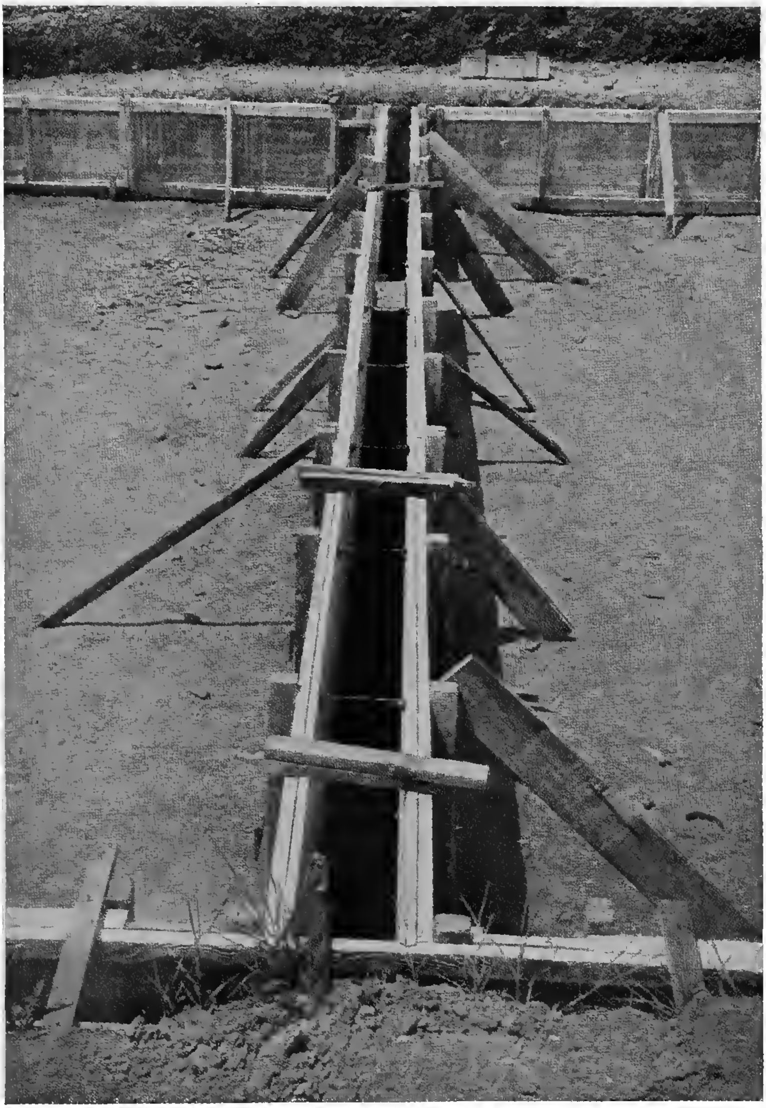
In building basement walls for a dwelling it is poor economy to make the cellar excavation just large enough. Make it a foot larger all around and then you can insure against water seeping into the basement through the walls. Use 1-2½-5 mixture for basement walls and always in wall construction it is wise to have at least a little 6-inch toe and heel at the base of the wall, thus:

The basement walls should be several inches thicker than the wall they are to carry. When the forms have been removed coat the outside of the wall with hot asphaltum before filling in the earth against the wall. Forms may be removed in a day or two days where there is no pressure on the work. In heavy work the forms should remain a week to three weeks.

For durable barn and cellar floors, put in a sub-base 5 or 6 inches thick of cinders and tamp. Then spread the concrete mixture 1-2½-5 about 3 inches thick and on this put an inch of a mixture of 1 part cement and 1½ parts sand. For steps use the stronger 1-2-4 mixture with the finishing mixture of 1 part cement and 1½ parts sand, and for sidewalks follow the directions as for barn or cellar floors, except using a leaner mixture, 1-2-5, and the same finishing mixture.

But never trowel the surface of floor, steps or sidewalk. Their primary purpose is to provide a secure, clean, and lasting footing, not to look and be slick and shiny. Finish such surfaces with a wire brush, if one is handy, otherwise use a straight-edge instead of a trowel. Sidewalks, of course, should have contraction joints at least six feet apart. They are made by laying the concrete in sections and separating the sections as laid with a thickness of heavy building paper.

As concrete is dumped into the form, firm it by tamping with a piece of scantling or a tamper until a little mortar appears at the surface. If voids appear, first be sure you have used the correct amount of sand and then cut down on the quantity of stone. If there seems to be an excess of mortar, add more stone. The important thing is to get the finer materials surrounding the larger stones. If the large particles of the coarse aggregate are three



THE FORMS MAY BE PREVENTED FROM BULGING BY BARS AND BRACES

inches in diameter and larger, care should be taken to tamp the mass extra well to be sure the large stones are surrounded by the fine material and that no voids are left. To give a smooth appearance to the surface of the concrete, place a flat, square end shovel, the back of the shovel against the form, and work up and down. This forces the larger particles toward the center and enables a larger quantity of the smaller material to flow up against the form.

In making tanks, troughs or other heavy above ground containers, woven wire of a size used in hog fences is excellent reinforcing. In walls for buildings the reinforcing, which consists of steel rods, varies so widely in the many different uses for which such walls are built that it is impossible to give in this space complete directions for all steel reinforcing.

A good mortar for laying stone is 1 part cement to 2 or 2½ parts sand. Workmen often add lime to cement mortar because lime makes the mortar work much more easily. But usually they add too much lime and thereby decrease the strength of the mortar.

CHAPTER XII

Irrigation and Drainage

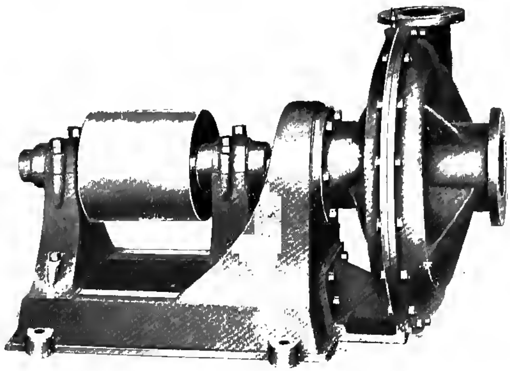
TOO much rain or too little rain causes crop failures and heavy losses. The best farming methods possible frequently are utterly unavailing before bad weather, droughts or too much rain. Weather is the greatest factor in farming, the most essential, changeable, and uncontrolled thing ever imposed on any industry. Control the weather, and the biggest handicap to farming is removed.

But it's absurd to suggest controlling the weather, some one remarks. Yes, that's true in a measure, but in the last few years quite a few farmers throughout the Mississippi Valley have found they can take the teeth out of the periodic summer drought by using a centrifugal pump to lift water from rivers, creeks or shallow wells onto the somewhat-level bottom-land fields. These men do not aim to irrigate continuously. They live in the rain belt, and don't have to. Their purpose is to supply water only occasionally in dry weather and thus to keep crops going until the rains surely will come again. It is not the whole period of drought that ruins, but the last week or two weeks just before the drought is broken.

A good example of how this new drought-breaking work is done is that of a Missouri farmer who protects twenty acres of his best corn land from drought and from too much rain by means of a little 4-inch centrifugal pump. This particular twenty acres that is made partly independent of the weather, lies in the old bed of a small river. It fills up with water if the spring rains or early summer precipitation happen to be a little generous and the crop on it is drowned out. It is practically useless in wet years. In favorable seasons it produces as well as any $150 an acre land in the valley. It would require a ditch almost two miles long, to the river, to drain this field. Efforts of the farm owner to form a drainage district met objection from neighbors.

It seemed a hopeless problem until some one suggested that the farm owner try a pump. The power to run it would cost him

nothing, since he had a 15-inch turbine wheel in his own water power plant, developing about twenty horse power under a 17-foot head of water. So he put in a 4-inch centrifugal pump in a shallow pit in the lowest point in the field, connected it with an electric motor, and laid about 100 feet of 4-inch pipe to discharge the



Irrigation and Drainage Needs can be Met Cheaply with this Type of Centrifugal Pump operated by Water Power

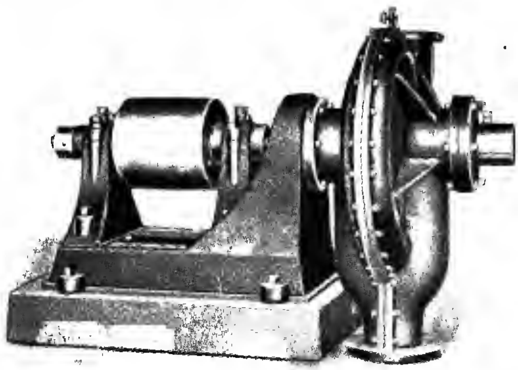
water through. He had to lift the water to a height of thirty feet to get it over a little hill or ridge and then a short distance beyond, where it would discharge into the natural drainage of a pasture.

It was wholly an experiment on that farmer's part, but it was a success. In rainy seasons the pump worked day and night, discharging 500 gallons of water a minute and saving the crop. It cost nothing to run it. It led to another successful experiment. One dry summer the owner dug a shallow well at the highest point in the field, put the pump and its motor in a wheel barrow and moved them up to the well. He found he could irrigate the field, since the power to run the pump as an irrigation plant cost the same as to operate it as a drainage plant—nothing.

This actual experience is worth the widest publicity that state or national agricultural agencies could give it. It is a progressive, practical example of how one farm made at least twenty acres independent of the weather. It is an introduction to another way of fighting bad weather successfully. It was installed entirely without technical advice and when the writer of this chapter first

saw it, had been in operation several years. The farmer was justly proud of his work, as he explained to the writer how he had installed the dual purpose, drainage and irrigation, plant.

"That little pump," he said fondly, "is 80 to 85 per cent efficient. My turbine over there is better than that."



WHERE THE WATER IS TO BE PUMPED TO MORE THAN ORDINARY HEIGHTS THIS TYPE OF CENTRIFUGAL PUMP IS DESIGNED TO BE MOST SERVICEABLE

"Your turbine wheel may rate that high, all right," replied the writer, "but your pump is nearer 50 than 80 per cent efficient."

Pressed for an explanation, the writer added:

"It isn't in the nature of these smaller centrifugals to have 85 per cent efficiency. An expensive plunger pump would be more efficient perhaps, but its cost would be so high you couldn't afford to install it. Your centrifugal is so much cheaper and yet so practical that it is the businesslike pump for you. You've got the right pump, all right, but you've crippled it badly by hooking it to a 4-inch discharge pipe. If you had only changed the size of the pipe, used a 5-inch pipe, you could have increased the efficiency of your pump 12 or 15 per cent."

"But I've made good money running this pump," protected the farmer.

"Of course you have. And you could have made better money by paying a little more for an inch-larger pipe. It's this way: You have to raise that water to a height of thirty feet and carry it a distance of 100 feet through the pipe, don't you? There's

bound to be friction between the water and the walls of the pipe, isn't there? Well, you're jamming 500 gallons of water through 100 feet of 4-inch pipe a minute and the friction in putting so large a quantity of water through so small a pipe in a minute is tremendous. It is equal to having to pump that water an additional twenty-five feet higher than the top of that little 30-foot ridge you have to lift it over. If you had a 5-inch pipe here, the friction would be equivalent to having to lift the water only an additional six feet higher; and if you had a 6-inch pipe, the friction would be equivalent to raising the water only three feet high.

"Now you can't change the fact that you have to lift the water thirty feet high to get it over that ridge, but you can change the size of the pipe and cut down the friction greatly. No, this mistake in using the wrong size of pipe doesn't hurt here because your power costs you nothing, but if you were using a gasoline engine or buying, instead of making your own electric current, it would be pretty expensive. Here is where you lose. You have to use a 10-horse power motor to pump through that 4-inch pipe. You could use a motor at least two horse power smaller and save $50 in the purchase price of the motor if you had a 5-inch pipe. That saving of $50, however, would not be net since your 100 feet of 4-inch pipe cost you $44 and 100 feet of 5-inch pipe would cost you $59, leaving a net saving of $35 which is worth saving. No, I do not believe that the 6-inch pipe would be feasible. It would cost $78, but at that maybe the resultant saving of $15 might be all right. It's simply a question of using the expert advice of a reliable manufacturer when you are considering employing any device for handling water. As you have done, it is easy for any practical man to install a successful and economical water power plant and to adapt it to drainage, irrigation or other work."

This incident is repeated here for its real worth in showing still another use of the home water power plant and as an illustration of the advantages to be gained in consulting reliable and competent expert opinion. If after you have read the text of this book, you will turn to the pages in the last part, giving pipe friction tables and other tabulated information, you will find it is time well spent in looking at them carefully for a bit. Any water problem that they do not seem to apply to will be quickly and accurately explained if you will write a letter to the Rodney Hunt Machine Company, Orange, Massachusetts.

CHAPTER XIII

Pure Water and How to Get It

THE whole world is water marked to an extent most of us never take time to realize. The human body is 70 per cent water, practically all the soil from which comes the food we eat is made by erosion, the freezing, thawing, and dissolving action of water, and the greatest expenditure of energy in the world is in the moving of the tides, the flowing of brooks and rivers, the evaporation and condensation of water. It is the most widely and generously distributed material on the face of the globe. It is the one great tangible substance perhaps most necessary to life, but, like the fish that was born to take water for granted, most of us never give water more than an instinctive thought.

We have seen in the preceding chapters how energy in water may be put to broad and beneficent use, to generate electricity and run machinery. This chapter takes up the nature of water in household use, the safeguarding of the home water supply, the curing of polluted and hard waters. This subject has nothing to do with water power development, but it is included here because it is the intention of this book to be a comprehensive and reliable work on water for home, school, and community reference.

Very, very few men since the day Adam quaffed his first cup of that celebrated brew, Adam's Ale, ever have drunk so much as one tumbler of pure water. Pure water does not exist in nature. Rain water is not pure. It takes up carbonic acid, certain harmless bacteria and other substances from the air, and since it contains these things, it is not pure. It is wholesome, but it is not pure. The only pure water is artificial water, distilled water, which is flat, tasteless, and mildly unpleasant for drinking purposes until it is brought into contact with air by being aerated.

Rain water is particularly desirable because it is soft. The quality of softness in water consists of the absence of certain

mineral salts. Soft water requires less soap than hard water. Hard water costs more than 100 million dollars a year in soap loss or waste alone in the United States, it is authoritatively estimated. Try to make a lather in a basin of hard water. First, a considerable quantity of the soap must unite with the "hardness," the mineral salts, and that quantity of soap is wasted in forming with the "hardness" soap curds, grayish-white coagulations of soap and minute particles of lime and magnesia that float on the surface and that decidedly are not lather. After a quantity of soap has produced these soap curds, then a second quantity of soap may form a lather, which demonstrates how hard water requires much more soap than soft water.

In addition to this huge soap loss the loss in boiler and pipe damage through corrosion and incrustation by hard water also runs far into the millions of dollars annually. It probably is a conservative assumption that the billions of dollars the World War has cost could be paid by the saving in soap, pipes, and boilers in the next generation, possibly in the next decade, if the world could eliminate hard water in domestic and industrial uses. On the other hand, physicians have noted an apparent greater tendency to goiter among inhabitants of certain Alpine districts and in other regions where the natural waters are soft and where, consequently, soft water only is used. While hard water is an immense loss to steam plants, so much so that many railroads and industries have installed water-softening plants to supply their boilers and for other uses, it makes absolutely no difference to the turbine water wheel or the rim-leverage wheel whether hard or soft water is used. Hard water does not damage them, which adds just one more advantage to the long list of advantages water power production has over any other form of power production.

Besides rain water, there are two general classifications of natural waters: surface waters and ground waters. Surface waters are the waters in streams and lakes. Ground waters are the waters below the surface of the ground. The natural waters of a large part of New England and the Rocky Mountains are soft, but in by far the greater part of the United States and the world, the natural waters are hard. Rain water trickling through soil and earth takes up lime and magnesia. To use chemical terms,

the water then has in solution bicarbonates of calcium and magnesium, and is hard water. It is called temporary hard water because it can be softened by boiling, as is shown by the scale that forms in tea kettles. Also, odd as it may seem, this water may be softened, made to precipitate its lime and magnesia, by the addition of a small quantity of hydrated lime. Permanently hard water contains chlorides, sulphates, and nitrates of calcium and magnesium, and other substances. It is said to be permanently hard because it cannot be softened by boiling. Almost all ground waters contain iron. The iron can be removed by aerating, letting the water fall from one shallow tank to another so that the thin sheet of falling water is struck by the air, the oxygen of which starts a chemical reaction with the iron in solution and causes it to be precipitated in a thick, rust-colored slime. Sand, gravel, and charcoal filters remove most of the iron that remains in suspension. The other minerals in the permanently hard water, such as the chlorides, sulphates, and nitrates of calcium and magnesium, are removed and the water softened by the addition of soda ash, the water then being allowed to settle in settling basins.

These methods of softening water may be successfully and easily applied to home needs by using two or three barrels and a small quantity of lime or soda ash, both of which are cheap. The quantity of lime or soda ash to use varies with the degree of hardness of the water and no general recipe or formula will apply to all waters. Where hard water works a real inconvenience, a home water-softening plant will save much labor and dollars and cents, in soap and in preventing damage to automobile radiators, water heaters and boilers. The necessary procedure is to send a sample of the water to a reliable laboratory and obtain an analysis and directions for treating. This is the most expensive part. The rest is to fill a barrel with water and put in the tiny amount of lime or soda ash called for in the directions, let the water settle and then draw it off into a soft water barrel.

A few restricted areas have waters so strongly impregnated with minerals it is almost impossible to treat them—for example, the black alkali waters of certain districts in the West. The washing powders sold to soften laundry and dish water constitute simply another form of the soda ash method of softening water; only, the softening of the comparatively small quantity of dish and

laundry water by dumping in an indeterminate quantity of washing powder is many times more costly than by softening much more water as suggested in the foregoing.

A cistern embraces a cheap method of avoiding hard water in limited household use. The cheapest dimensions for a cistern are given in the chapter on concrete construction in this book. As cistern water is stored rain water, usually, it must be remembered that rain water attacks lead pipes or any form of lead it comes in contact with and that if it is carried through lead pipes, painfully acute, if not fatal, lead poisoning may result. Hard water softened by lime or soda ash, however, remains sufficiently alkaline so that it does not react with lead and hence will not cause lead poisoning. Lead pipe, luckily, has gone almost entirely out of use in modern plumbing. Galvanized iron pipe is cheaper and better.

The old saying that, "Water purifies itself every hundred feet," is a harmful hoax. A pond or lake purifies itself more quickly by sunlight and sedimentation than does a running stream. Germs are not bugs, which is a common notion. They are tiny, delicate plants that usually live only a few days. There are exceptions to this, for the spores of the tetanus germ, which causes lockjaw, will live for years under most unfavorable conditions of heat and dryness. Tetanus, however, is not a water-borne disease and need not be considered in relation to the water supply. Typhoid, the chief water-borne disease, may lie dormant for weeks in snow and ice and then become virulent with the first thaw that washes it into a water course. But usually it dies within a week. Sunlight, sedimentation and other micro-organisms kill it. Algæ, the green scum that forms in tanks, ponds, and still waters, also acts to purify water. Muddy streams are frequently less infected than clear streams because the clay and silt in suspension in the muddy streams carry the bacteria to the bottom. It is what bacteriologists call the "resistant minority," the very few extra-vigorous and hardy germs that resist nature's sterilizing agencies, that causes the trouble. They must be guarded against wherever water is used.

Cities have practically eliminated typhoid by sedimentation and by treating the water with chlorinated lime, commonly and incorrectly called chloride of lime, which can be bought for fifteen or twenty cents a pound in small quantities. The records show

that cities that impound water a considerable time in reservoirs have better water than those that store water a shorter time. Storing water in ponds or reservoirs or tanks is practicable in any country home having water power, and further adapting the successful city and army use of chlorinated lime for purifying water for home use can be done by following the directions herewith:

With a wooden stick stir a half pound of chlorinated lime in a granite, earthen or glass container several minutes. Add enough water to make a gallon of the solution. Then dissolve thirteen ounces of sal soda in a half gallon of lukewarm water to which is added five ounces of soda ash. Add more water to make a gallon. Mix the two solutions in an earthenware, granite or glass container—never in metal—and after it has settled pour the clear solution into bottles, cork tight and set in a cool, dark place for future use. Keep the solution out of reach of children, for it is corrosive and poisonous. This stock solution will last a year, and one ounce of the solution will sterilize 100 gallons of water. Water in a cistern or wooden tank can be treated with the proper amount of the solution by determining the quantity of water and adding an ounce of the solution for each 100 gallons of water. The quantity of water in a cylindrical container may be determined by multiplying .7855 by the diameter of the container, then multiplying that result by the diameter again and then by the depth of water. That will give the contents in cubic feet and the number of gallons may be determined by multiplying the cubic feet by 7½. It is understood that the diameter is computed in feet, not inches.

Algæ, tiny aquatic plants, that frequently form green scum in stock tanks, are harmless. Their chief disadvantage is that they are in the way and that some varieties give off an offensive odor. They may be eliminated by adding five grains of copper sulphate to each 100 gallons of water to be cleared up.

Most ground waters are free of germs, if not infected by seepage from human habitation. For this reason cisterns should not leak and wells should have water-tight walls the first fifteen or twenty feet below the surface. Below that distance it may be generally assumed that any seepage getting into the well will have been adequately filtered by the earth it has passed through. Below fifteen or twenty feet the walls of the well may be of loose

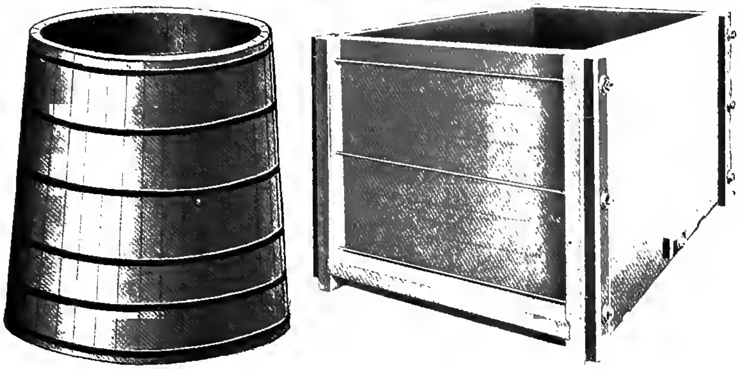
stone. Wells and cisterns should be covered tightly to prevent water from leaking in. Cesspools and other sources of infection should be located on ground lower than the well and so that seepage may drain off and filter through the soil and upper strata a sufficient distance from the well before it reaches ground water in the sheet or table of water that lies below the surface in most localities.

In closely inhabited areas well water is rarely safe, except from very deep wells. The soil and sub-strata become impregnated with pollution and no longer act as filters. Also the danger from fissures that form underground channels comparatively free from filtering materials is ever present, particularly so in limestone countries, threatening to lead seepage direct to the well or near it. A few years ago in a middle western town eight persons in one house had typhoid fever. All had drunk water from a well on the premises. Analysis showed the water infected with typhoid bacilli. Investigation revealed that there had been a case of typhoid fever in a house several blocks away. In the house where the typhoid case had been the investigator poured fluorescin into the drains. Some hours later water drawn from the infected well several blocks distant was colored by the dye, fluorescin. The sewer of the typhoid case house leaked and the seepage from it had found its way through a fissure and flowed down to the well or sufficiently near it to get into the water of the well.

There is more typhoid fever in rural districts than in cities, because cities can afford to hire experts and employ expensive methods of supplying wholesome water. Some one has correctly said that typhoid fever was not a disease but a disgrace, and that is true because typhoid can be prevented so effectively. First, sources of pollution, such as cesspools, should be as far as possible from and lower than the water supply. Second, by covering wells and cisterns and constructing their walls against seepage. Third, by pumping water from a distant spring, instead of using a well, and employing the power in the spring branch to do the pumping. Fourth, by pumping water from a brook or spring to a tank and treating with chlorinated lime.

It is not true that cows drinking from infected streams will transmit typhoid through the milk. Domestic animals do not con-

tract typhoid fever. But it is decidedly unwise to use water from a questionable source to supply drinking water for livestock or for any other use about the farm.



Typical Water Storage Tanks

The ordinary sand, gravel, and charcoal filters do not sterilize water. They remove some of the matter in suspension and are excellent for partly clarifying the water, but they soon fill up with sediment and rotting organic matter and not only cease filtering, but begin to pollute the water. Filters must be cleaned periodically to continue to filter. Treating with chlorinated lime, boiling, and using reliable baked clay filters are the only practical methods for home use in sterilizing water. Alum is used successfully in many large city plants as a part of the clarifying process, but there are some objections to its use and it should not be employed except under competent supervision. Settling, and sand, gravel and charcoal filters, that are kept clean, will do the clarifying sufficiently well for home use. In large water plants the water flows in one direction through the filters. When the filters have filled up with dirt a flow of water is sent through them in the opposite direction and the accumulations washed out.

When the neglected farm stream has at last been put to work furnishing electricity and power for the farm home, naturally the question arises, why not better fishing in the brook or creek? Why not, indeed, since the United States Government will gladly furnish free all the stock needed to restock the stream and will

deliver them without charge at the railroad station of the person applying for them. If the dam has formed a small pond in the stream the environment for better fishing may be made ideal. Black bass, rock bass, which are sometimes called goggle-eye or red-eye, crappie, yellow perch, black perch, and sunfish are excellent varieties to choose. Rainbow, brook and steelhead trout should hardly be placed in waters where the temperature of the water rises above 70 degrees. Application for fish should be made to the Bureau of Fisheries, Washington, D. C. Many states also maintain fish hatcheries and supply fish free for stocking streams and ponds in the state.

CHAPTER XIV

Installing a Water Power Plant

COMMON sense covers practically everything there is to know in putting in a home or small town power plant. Situations vary so widely that it is impossible to give detailed directions that are not covered by plain reasoning, because the mechanism of water power apparatus is so simple and because water in motion has but one chief attribute to be controlled, the well known characteristics of running down hill. There is perhaps only one general rule that is appropriate here, and that is to be sure that the tail race takes the water off quickly from the discharge from the turbine wheel. Water in the tail race, should not be allowed to back up around the end of the discharge pipe, for in so doing it will impede the discharge and the discharge in turn will impede the wheel and result in loss of head and consequent loss of power. Wherever required we will gladly furnish plans and full directions. The smaller wheels are shipped whole and ready to set in place. The larger wheels are so plainly marked and their purpose and place so quickly apparent that no time need be lost by assembling them with inexperienced hands. Setting up a grain binder is much more intricate and complex task than installing a water wheel.

On page 128 is a diagram of the small home power plant and machine shop previously pictured. The turbine wheel at the bottom is connected by a quarter-turn belt to the line shaft at the top. The line shaft in turn is belted to an electric generator at the left, the picture showing position of storage battery and switchboard. In the center the line shaft drives a pump and at the right, a wood saw. Other machines could be belted to the line shaft by using the same pulley wheels on the same shaft and supplying longer belts or by the addition of more pulleys. The small stand and wheel at its top marked "gate wheel" control the turbine wheel gates.

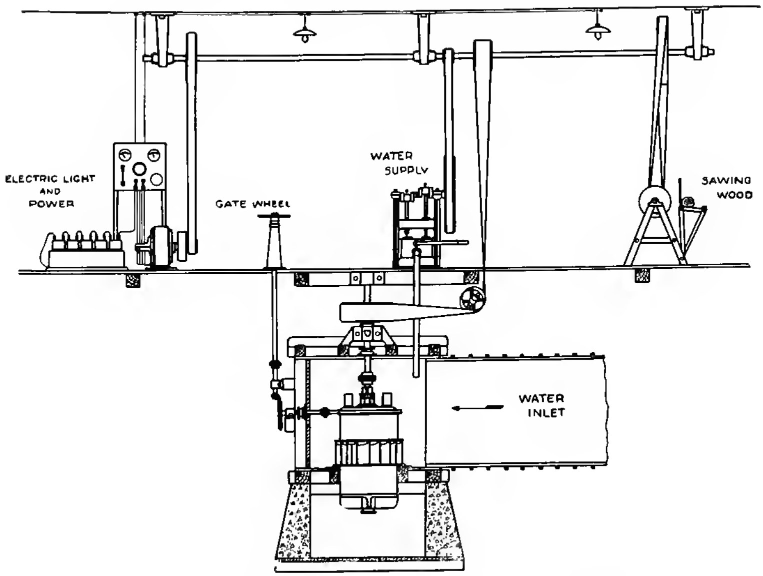


DIAGRAM OF INSTALLATION OF A HOME POWER PLANT

The diagram on page 129 shows the wheel pit of the same home power plant. The wheel is supported by two wooden beams on a concrete base, which also supports the wheel pit. You will notice that the dead water in the wheel pit rises only a short distance about the end of the discharge of the wheel at E. M shows the gates of the wheel, and inside the case at A is the mechanism that works the gates and which is attached to the coupling at 17 and 18 and extends out through the water-filled wheel pit through a packing gland at 15 to the beveled gear at 14 which connects at 13 with a cogwheel that transmits to the gate mechanism every turn of the hand wheel at 8, which is mounted on a stand in the power plant. The diagram is made for reference and directions in the taking of measurements. The turbine wheel is coupled to the driving shaft of the pulley by the coupling at 2 and passes out of the wheel pit through a packing gland that prevents leaking.

A man may have a complete "ready made" power plant, including water wheel, flume, penstock, gate, gate hoist, trash rack, forebay, dam and all shipped complete and ready to be assembled

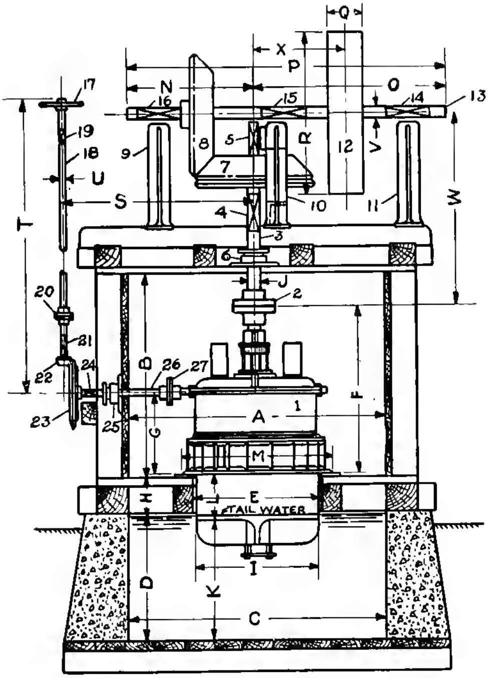
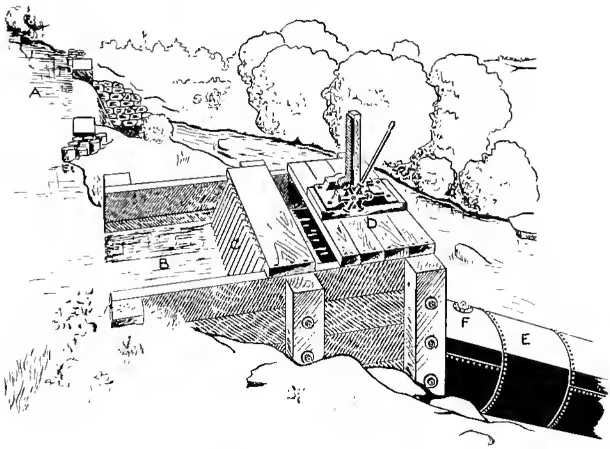


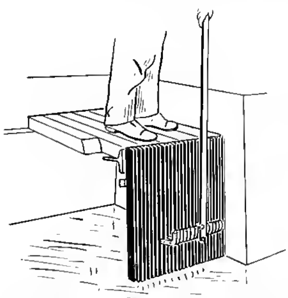
Diagram of Turbine Wheel Pit Installation

in its designed place on his brook, creek or river power site, just as he may buy a suit of clothing all ready to wear. On page 130 is pictured the source of the water power plant's power. In the left background at A is the dam. In the foreground at B is the forebay. C is the trash rack and D the gate hoist to control the flow of water into the penstock E. When this gate is closed the penstock E is emptied by opening the gates of the wheel, in which case it is frequently an advantage to have the little air inlet valve F in the penstock to let air into the penstock automatically, thus relieving the penstock of outside air pressure, as the draining of the penstock naturally creates a vacuum within the penstock. Such a vacuum would be a heavy strain on any type of construction, but in this case the simple little air inlet valve relieves the pressure immediately. This picture shows an ideal arrangement for the home or small town power plant. It has every practical convenience and refinement that the huge water power plants have.



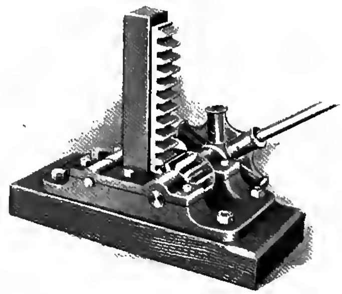
The Intake of a Town or Home Power Plant

The trash rack shown in the picture at C, and reproduced in a small sectional view on this page is a sturdy barrier between the whole plant and prevents damage to intake, flume, penstock or any part of the plant. Trash racks are necessary whether to keep out leaves and light trash or to protect from ice or the heavy debris of high water. Homemade trash racks frequently are very efficient and all that is necessary; but it must not be presumed that the trash rack made by even a skilled carpenter can be compared with the expert make that has grown through study and experience, just as the modern dam has developed from an over-large and unsafe pile of material to a comparatively small and safe structure of technical design. The back bar trash rack shown in this picture is a stronger wall and yet lets more water through than is possible with a homemade trash rack. Trash racks are designed for different peculiarities in canals, flumes and penstocks. They are set at various angles to meet different conditions and we shall be glad to advise water power plant owners fully on this small particular also.

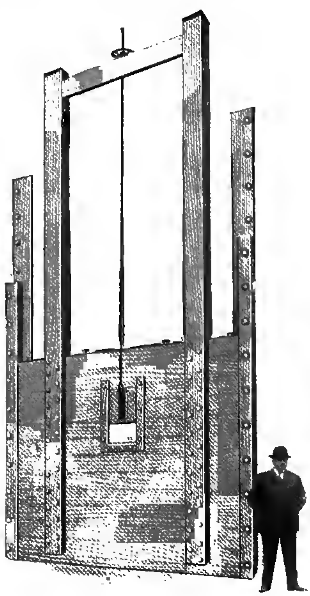


A Section of a Trash Rack and an Unbreakable Steel Trash Rack Rake Being Used

The single gear gate hoist is a simple and perhaps as complete a device as the small plant may need. The perpendicular stem attaches to the gate and the gate is raised or lowered by working the hand lever, as shown in the lower picture on this page. Wood gates are made of hard pine, oak or chestnut and in any size necessary. Like the dam and the trash rack, they have been developed to have strength where strength is necessary and they have eliminated all unnecessary weight and material. The well designed gate, whether of wood or metal, has no unnecessary waste of material, for every ounce of clumsiness costs money and it further detracts from the ease and quickness that should belong in the operation of any gate. The picture herewith is of a very large gate for a canal, dam, or flume. The small opening in the center is a "filler gate" to make the gate quicker and easier of operation. Small gates do not need "fillers." A small power plant may get along very satisfactorily without a gate at the intake, for the closing of the wheel gates stops the flow of water through the wheel. They may



Single Gear Gate Hoist

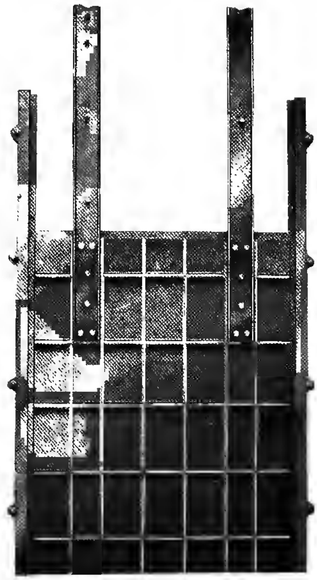


A Large Gate for Dams, Canals or Flumes

not be wholly necessary, perhaps, but are very convenient pieces of equipment to have. But the trash rack, either homemade or of expert design, is an essential. On the following pages are pictures of several types of metal gates and of gate hoists, made for large power installations. The small home or town water power plant is blessed by not having to install such heavy equipment, which is shown here as a small indication of how far water power development has reached toward perfection in all things. Big industries with all best technical advice necessary in choosing the form of power that is cheapest and best for their use have made this perfection possible by choosing water power.

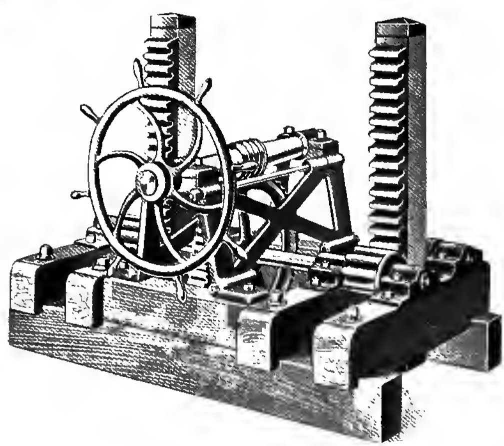
Only a few water power accessories are mentioned here but we design and manufacture everything for water power plants, for the most economic and durable construction and operation of those plants. Many accessories and refinements are not necessary in the small plant, where they might be quite essential in the larger plant. They are mentioned here because pride of ownership and the general satisfaction of "dressing up" a plant frequently adds to the convenience they afford. We have a special gear department for furnishing gears of the best proportion and durability, and carry a full stock of maple from which to make either machine cut or handdressed cogs and keys for mortise gears, in case gear transmission is used in the water power plant.

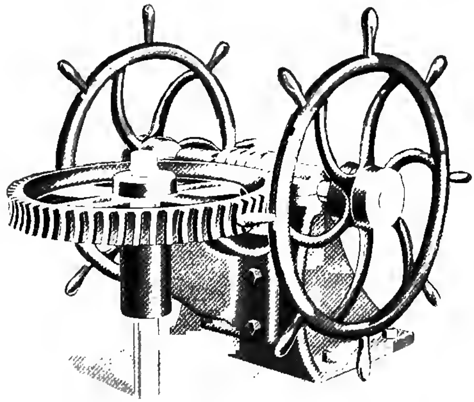
AT THE RIGHT—A GATE FOR SQUARE OR RECTANGULAR OPENINGS



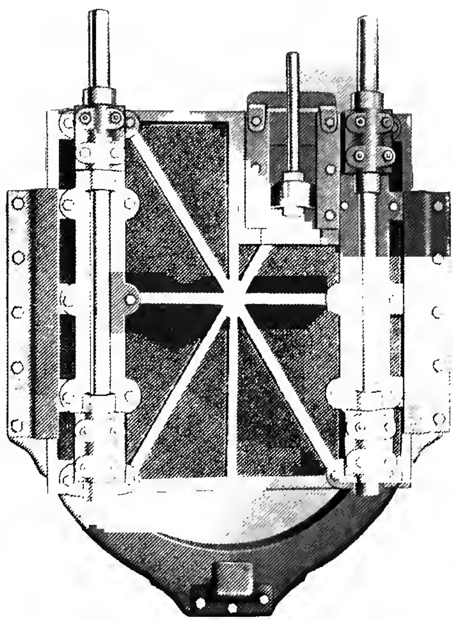
AT THE LEFT—A QUICK-ACTING GATE VALVE, SIZES 14 INCHES AND UNDER

AT THE RIGHT—A WORM WHEEL AND SPUR GEAR GATE HOIST



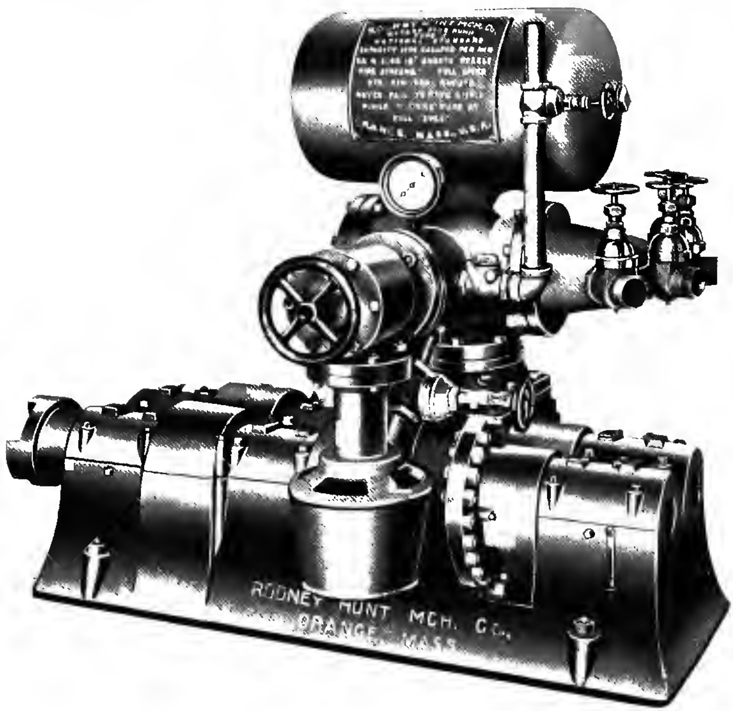


Worm Wheel and Worm Gear Gate Operating Device



A Metal Gate for Round or Square Openings

Where a town or village, or private individuals in either, contemplate bettering the whole community by utilizing a nearby stream to furnish light and power, to supply a water works system and fire protection, a turbine wheel, or a pair of wheels, an electric generator and a rotary pump are all the machinery necessary.



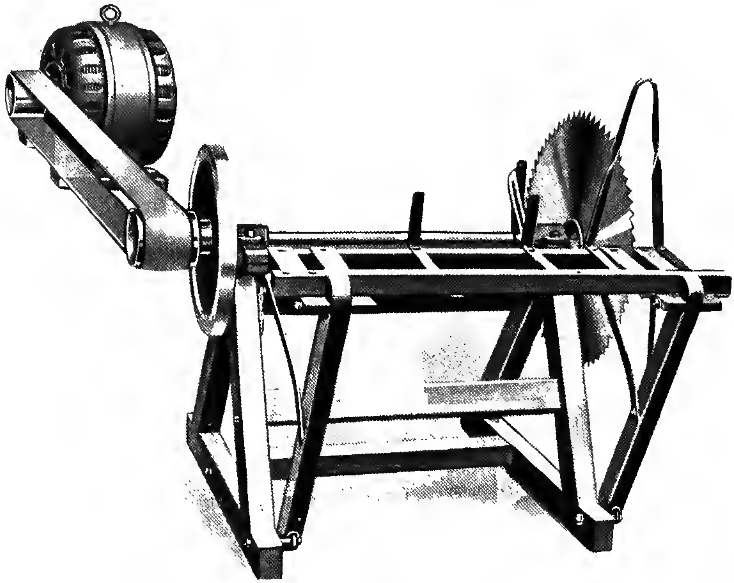
The Rotary Pump Affords Dependable Water Supply for Town and Industrial Water Works Systems as Well as Ample Fire Protection

The turbine wheel will provide all the power needed to operate generator and pump with no expense for fuel and at practically no maintenance or repair cost. It may be connected directly to pump and generator or geared or belted to them. If the water to supply the water works system is a spring some distance from the stream supplying the power, the rotary pump may be installed at the spring and operated by an electric motor connected by two wires with the generator in the power plant. The picture on the

preceding page shows a pump for town, factory, or mill water supply and fire protection. It is the most capable and lasting type of rotary pump design and combines, with large capacity, force to deliver the water under high pressure. It probably requires less attention than any other kind of pump made. Its history has been a constant development of improvement for more than thirty years in which we have been making rotary pumps. It was at first designed to meet the very rigid requirements of fire underwriters in a pump for fire protection in large mills and factories where huge volumes of water might be wanted at any moment and under heavy pressure. Some years ago a New York state mill conceived the idea of using the pump for a dual purpose, to supply the town with water as well as to protect the mills from fire. It was found to work so well in this double duty that other pumps have since been installed solely for town water works or for such dual purposes. Town or village officers considering a pump for a water works system should investigate the capabilities of the rotary pump. The type of pump shown here has never failed to live up to entirety the constantly more exacting requirements of the fire underwriters, who never yet have failed to accept the pump as meeting all their high standards. There could hardly be a better recommendation for a pump than this record.

Perhaps the cheapest arrangement for using water power in the home is to build a small structure above a turbine wheel pit and place in that building all the machinery to be operated. In this way the wheel's power would be utilized without the necessity of buying an electric motor to operate a machine that was some distance from the power plant. Frequently it is not convenient to have such a combination of power plant and machine shop, so the power plant houses only an electric plant and its power is transmitted to any point by means of wires. For example, a saw, shown in the picture on page 137 may be a mile or more from the power plant and be operated by the electric motor, shown in the background of the picture. The same motor in turn could be belted to any other machine within reasonable range of the motor's capacity. The pump at the well could be similarly operated and the operation of all the stationary machinery about the place, cream separators, ensilage cutters, feed mills, or even the separator

of a threshing machine, provided the power plant and the necessary motor were large enough to handle them. In the household one or more small motors could do duty in relieving much of the drudgery that goes with churning, washing, sweeping and other



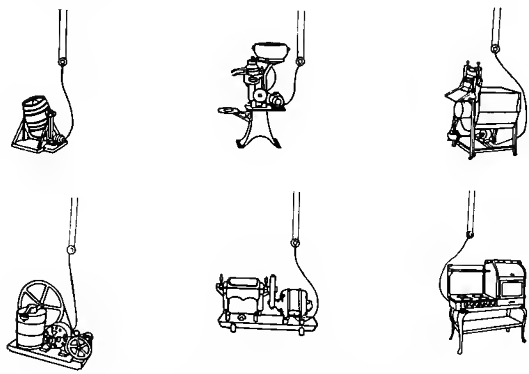
Wood Saw Operated without Cost for Power through Electric Motor that Derives its Current from a Home Water Power Plant

unending tasks. But for sawing wood and pumping water alone the power plant is a paying investment, to say nothing of the extra convenience and pleasure of having electric light, heat, and power, as the sorely beset Hivites could assert if they were present to testify.

It will be remembered that some thousands of years ago the Hivites, conquered, were the professional hewers of wood and drawers of water. They didn't choose their calling. It was thrust upon them. That was in a day when being mean to somebody was one of the highest and most practiced arts. The princes of the congregation in looking about for a particularly mean way of being mean to the conquered Hivites decided that punishment

by death was too easy. So they made the Hivites hewers of wood and drawers of water.

The question naturally is, "Oh, why be a Hivite, when the brook across the pasture calls to you to put an end to that form of slavery or drudgery?"



SIX FORMS OF THE MOST MODERN HOUSEHOLD CONVENIENCES THAT THE HOME WATER POWER PLANT MAKES POSSIBLE AND THAT WILL MAKE ANY COUNTRY HOME SUPERIOR IN CONVENIENCES TO THE AVERAGE, MODERN CITY HOME

APPENDIX

Ready Information Compiled to Aid in Realizing the Nation's Greatest Chance for Utilizing its Greatest Water Power, the Combined Opportunities of the Home and Small Town Water and Electric Plant.

From the Scientific American of July 21, 1917

Our large water power possibilities are being developed perhaps as rapidly as is justifiable, all things considered. The small powers, where the rights involved all lie within the title of one or two property holders, are free from the legal troubles which so often hamper the larger projects; but their development seems almost prohibited by the necessarily high cost of determining all the engineering values involved. Nevertheless, with the rapid development of uses for the small motor in driving almost every contrivance about the farm, and the increasing production of labor saving contrivances to be driven, a source of small power for isolated places is becoming daily more imperative. There are, of course, small engines that are partly filling this growing demand, but where water power is available it has obvious advantages. But how to apply it effectively is a matter involving so many questions which, while engineering commonplaces, are as Greek to the farmer and rural resident, that the small water power lags far behind its bigger brother in making itself useful. The solution of the problem would seem to be along the line of standardization . . . . From the point of view of one who is familiar with the incredible cost reductions effected by standardization in construction, the stream must be adapted to a standard dam, even if the dam chosen be half or twice as large as good engineering would demand. Why should not our smaller streams be systematically surveyed and classified with respect to their power possibilities? Why should we not have half a dozen or a dozen standard turbines, both vertical and horizontal, of various horsepower from perhaps two to three to, say, ten or twelve, with standard gear change apparatus and other standard accessories, perhaps even with standard dams and spillways? ... ... With such standardization seriously put before the owners of our little water powers, surely it would not be long before these would become in truth our great water powers, dwarfing in extent and value of their application the combined forces of a dozen Niagaras.

THE SIZE SPACE A TURBINE WHEEL OCCUPIES—TABLE OF DIMENSIONS
HUNT-FRANCIS TURBINES

Size of Wheel.	Diam of hole to be made through floors of flume.	Diameter of top flange on draft-tube	Size of flume inside of planking	Depth of draft-tube.	Size of Shaft	Height from under side of flange to center coupling.	Depth of pit, from end of draft-tube to bottom of wheel-pit.
9 inch.	1 ft. 4 in.	2 ft. 1 in.	4 ft.	1 ft	1½ in.	2 ft. 3 in.	1 ft. 2 in.
12 in.-No. 2	1 ft. 7 in.	2 ft. 4 in.	4 ft. 3 in	1 ft.	1¾ in.	2 ft. 6 in.	1 ft. 3 in.
12 in.-No. 1	1 ft. 7 in.	2 ft. 4 in.	4 ft. 6 in	1 ft.	1¾ in.	2 ft. 4 in.	1 ft. 5 in.
15 inch.	1 ft. 10 in.	2 ft. 7 in.	4 ft. 9 in	1 ft. 1 in.	2 in.	2 ft. 9 in.	1 ft. 6 in.
18 inch.	2 ft. 5 in.	2 ft. 11 in.	5 ft.	1 ft. 2 in.	2½ in.	3 ft. 2 in.	1 ft. 8 in.
21 inch.	2 ft. 5 in.	3 ft. 1 in.	5 ft. 3 in.	1 ft. 3 in.	3 in.	3 ft. 7 in.	2 ft.
24 inch.	2 ft. 11 in.	3 ft. 4½ in	5 ft. 6 in.	1 ft. 3 in.	3½ in.	3 ft. 11 in.	2 ft. 5 in.
27 inch.	3 ft. 1½ in.	3 ft. 8¼ in.	6 ft.	1 ft. 3 in.	4 in.	4 ft. 2½ in.	2 ft. 8 in.
30 inch.	3 ft. 4½ in.	4 ft.	7 ft.	1 ft. 4 in.	4 in.	4 ft. 6 in.	3 ft.
33 inch.	3 ft. 5¼ in.	4 ft. 4 in.	7 ft. 6 in.	1 ft. 5 in.	4½ in.	4 ft. 9 in.	3 ft. 3 in.
36 inch.	3 ft. 10 in.	4 ft. 8 in.	8 ft.	1 ft. 5 in.	4½ in.	4 ft. 10 in.	3 ft. 8 in.
39 inch.	4 ft. 1 in.	5 ft.	8 ft. 6 in.	1 ft. 6 in.	5 in.	5 ft. 1 in.	3 ft. 10 in.
42 inch.	4 ft. 4 in.	5 ft. 4 in.	9 ft.	1 ft. 6 in.	5 in.	5 ft. 5 in.	4 ft.
45 inch.	4 ft. 7 in.	5 ft. 7 in.	9 ft. 6 in.	1 ft. 7 in.	5½ in.	5 ft. 9 in.	4 ft. 4 in.
48 inch.	4 ft. 10 in.	5 ft. 10 in.	10 ft.	1 ft. 7 in.	5½ in.	6 ft.	4 ft. 8 in.
51 inch.	5 ft. 3 in.	6 ft. 1 in.	10 ft. 6 in.	1 ft. 8 in.	6 in.	6 ft. 2 in.	4 ft. 10 in.
54 inch.	5 ft. 5½ in.	6 ft. 4½ in.	11 ft.	1 ft. 8 in.	6 in.	6 ft. 4 in.	5 ft. 2 in.
57 inch.	5 ft. 8 in.	6 ft. 7½ in.	11 ft. 6 in.	1 ft. 9 in.	6 in.	6 ft. 6 in.	5 ft. 4 in.
60 inch.	5 ft. 11 in.	6 ft. 10½ in.	12 ft.	1 ft. 9 in.	6 in.	6 ft. 9 in.	5 ft. 6 in.
66 inch.	6 ft. 6 in.	7 ft. 3½ in.	13 ft.	1 ft. 10 in.	7 in.	7 ft. 2 in.	5 ft. 8 in.
72 inch.	7 ft. 1 in.	8 ft.	15 ft.	1 ft. 11 in.	8 in.	8 ft.	6 ft.
80 inch.	7 ft. 9 in.	8 ft. 8 in.	17 ft.	2 ft.	9 in.	8 ft. 3 in.	6 ft. 8 in.
88 inch.	8 ft. 5 in.	9 ft. 4 in.	17 ft. 6 in.	2 ft. 4 in.	9½ in.	8 ft. 6 in.	7 ft. 4 in.
96 inch.	9 ft. 1 in.	10 ft.	18 ft.	2 ft. 8 in.	10 in.	8 ft. 9 in.	8 ft.

Capacities Hunt-Francis Turbines

Head.	9 INCH WHEEL. 19 Square Inch Vent			Head.	9 INCH WHEEL. 19 Square Inch Vent.			Head.	9 INCH WHEEL. 19 Square Inch Vent.		
	Horse Power.	Cu. ft. Min.	Rev. Min.		Horse Power.	Cu. ft. Min.	Rev. Min.		Horse Power.	Cu. ft. Min.	Rev. Min.
4	.78	127	258	**46**	31.11	430	876	**88**	82.00	594	1211
5	1.09	142	289	**47**	32.11	435	885	**89**	83.44	597	1218
6	1 47	155	316	**48**	33.18	440	895	**90**	84.88	600	1225
7	1 82	168	342	**49**	34.22	444	904	**91**	86.32	604	1231
8	2 23	179	365	**50**	35.23	449	913	**92**	87.76	608	1238
9	2 65	190	387	**51**	36.27	453	922	**93**	89.24	611	1245
10	3.12	201	408	**52**	37.47	458	931	**94**	90.72	615	1252
11	3.58	210	428	**53**	38.43	462	940	**95**	92.20	618	1258
12	4.13	220	447	**54**	39.47	466	949	**96**	93.68	622	1265
13	4.63	229	466	**55**	40.54	471	958	**97**	95.21	625	1272
14	5.19	237	483	**56**	41.78	475	966	**98**	96.74	628	1278
15	5.72	246	500	**57**	42.88	479	975	**99**	98.17	631	1284
16	6.33	254	516	**58**	44.02	483	983	**100**	99.60	634	1291
17	6.95	266	532	**59**	45.18	487	992	**101**	101.12	638	1298
18	7.59	269	548	**60**	46.08	491	1000	**102**	102.64	641	1304
19	8.20	277	563	**61**	47.54	496	1008	**103**	104.16	645	1310
20	8.90	284	577	**62**	48.65	500	1016	**104**	105.68	648	1316
21	9.49	290	591	**63**	49.86	503	1025	**105**	107.06	651	1322
22	10.25	297	606	**64**	51.03	508	1033	**106**	108.44	654	1329
23	10.97	304	619	**65**	52 23	512	1041	**107**	109.82	657	1336
24	11.71	311	633	**66**	53.01	516	1049	**108**	111.20	660	1343
25	12 45	317	646	**67**	54 61	519	1060	**109**	112.78	663	1349
26	13.21	324	658	**68**	55.92	523	1066	**110**	114.36	666	1354
27	13.90	330	671	**69**	57.23	527	1073	**111**	115.99	669	1360
28	14 69	336	683	**70**	58.37	531	1080	**112**	117.52	672	1366
29	15.50	341	695	**71**	59.61	535	1083	**113**	119.14	675	1372
30	16 40	347	707	**72**	60.91	539	1096	**114**	120.76	678	1378
31	17.60	353	719	**73**	62.14	542	1103	**115**	122.38	680	1384
32	17.90	359	730	**74**	63 45	547	1112	**116**	124.00	682	1391
33	18.26	365	742	**75**	64.76	550	1118	**117**	125.80	685	1397
34	19.72	370	753	**76**	66 03	553	1127	**118**	127.60	688	1404
35	20.50	375	764	**77**	67.36	557	1133	**119**	129.40	691	1409
36	21.25	381	775	**78**	68.69	560	1140	**120**	131.20	694	1414
37	22.16	386	785	**79**	69.96	564	1148	**121**	133.60	697	1420
38	23.07	391	796	**80**	71.00	568	1155	**122**	136.00	699	1426
39	23.98	396	806	**81**	72.67	571	1162	**123**	138.40	701	1432
40	24.92	401	817	**82**	74.03	575	1169	**124**	140.80	704	1438
41	25.89	406	827	**83**	75.40	578	1176	**125**	142.65	705	1443
42	26.84	411	837	**84**	76.84	582	1183	**126**	144.50	708	1449
43	27.82	416	847	**85**	78.14	585	1190	**127**	147.65	711	1454
44	28.78	421	857	**86**	79.44	588	1197	**128**	148.20	716	1460
45	29.75	427	866	**87**	80.91	592	1204	**129**	148.70	721	1466

Capacities Hunt-Francis Turbines

Head.	12 IN. WHEEL No. 2. 28 Square Inch Vent.			12 IN. WHEEL No. 1. 38 Square Inch Vent.			15 INCH WHEEL. 57 Square Inch Vent.		
	Horse Power.	Cu. Ft. Min.	Rev. Min.	Horse Power.	Cu. Ft. Min.	Rev. Min.	Horse Power.	Cu Ft. Min.	Rev. Min.
4	1.16	187	207	1.57	254	207	2.36	381	179
5	1.63	203	237	2.19	284	234	3.29	426	189
6	2.17	229	254	2.94	311	254	4.34	466	207
7	2.61	247	269	3.64	336	269	5.47	504	224
8	3.32	264	282	4.46	359	282	6.69	539	238
9	3.95	280	301	5.30	381	301	7.96	571	253
10	4.64	296	319	6.24	402	319	9 36	603	266
11	5.34	310	334	7.17	421	334	10.79	632	280
12	6.09	324	347	8.20	440	347	12.30	659	292
13	6.89	337	362	9.26	458	362	13.90	687	304
14	7.72	350	376	10.38	475	376	15.58	712	315
15	8.52	362	389	11.45	492	389	17.17	738	326
16	9.41	374	402	12.66	508	402	18.99	762	337
17	10·34	386	414	13.90	523	414	20.90	785	347
18	11.28	398	426	15.19	539	426	22.79	808	357
19	12.20	408	439	16.40	554	439	24.60	830	367
20	13.24	418	450	17.80	568	450	26.70	852	376
21	14.16	428	462	18.99	582	462	28.49	873	386
22	15.25	439	472	20.50	595	472	30.73	893	395
23	16.29	448	483	21.94	609	483	32.91	913	402
24	17.38	458	494	23.42	622	494	34.90	933	411
25	18.51	468	504	24.90	635	504	37.39	952	417
26	19.49	477	514	26.42	648	514	39.60	971	427
27	20.69	486	523	27.81	660	523	41.71	990	436
28	21.85	495	534	29.38	672	534	44.09	1008	445
29	23.17	503	544	31.10	683	544	46.74	1026	454
30	24.35	512	553	32.80	695	553	49.20	1043	461
31	25.46	521	562	34.23	707	562	51.35	1060	467
32	26.65	529	571	35.80	718	571	53.71	1077	476
33	27.94	538	580	27.53	730	580	56.30	1094	484
34	29.21	545	588	39 44	740	588	58.16	1110	490
35	30.29	553	596	41.00	751	596	61.51	1126	497
36	31.42	562	604	42.50	762	604	63.77	1143	504
37	32.78	569	612	44.32	772	612	66.51	1159	511
38	34.14	577	620	46.14	783	620	69.20	1174	518
39	35.48	585	628	47.97	793	628	71.97	1190	524
40	37.00	592	636	49.85	803	636	74.78	1204	530
41	38.75	602	644	51.79	813	644	77.65	1219	536
42	40.10	610	652	53.69	823	652	80.54	1235	543
43	41.62	618	660	55.62	833	660	83.44	1249	549
44	42.27	625	668	57.56	843	668	86.31	1263	556
45	44.24	633	676	59.50	854	676	89.18	1278	563

Capacities Hunt-Francis Turbines

Head.	12 IN. WHEEL No. 2. 28 Square Inch Vent.			12 IN. WHEEL No. 1. 38 Square Inch Vent.			15 INCH WHEEL. 57 Square Inch Vent		
	Horse Power.	Cu. Ft. Min.	Rev. Min.	Horse Power.	Cu. Ft Min.	Rev. Min.	Horse Power.	Cu. Ft. Min.	Rev Min
46	45 83	637	684	62.23	861	684	93 35	1292	570
47	47.33	643	692	64.23	871	692	96.34	1306	576
48	48.90	648	700	66.36	880	700	99.56	1320	582
49	50.42	655	708	68.44	888	708	102.66	1333	589
50	51 87	662	717	70.47	898	717	105.71	1347	596
51	53.46	668	726	72.55	907	726	108.57	1360	603
52	55.06	675	732	74.94	916	732	112.14	1374	610
53	56.65	681	740	76.86	924	740	115.36	1386	616
54	58.24	687	748	78.94	933	748	118.56	1399	622
55	59.79	694	756	81.08	942	756	121.93	1412	628
56	61.56	700	764	83.57	950	764	125.25	1425	634
57	63.21	706	772	85.77	959	772	128.67	1433	640
58	64.88	713	780	88.04	967	780	132.05	1451	646
59	66 56	719	787	90.37	975	787	135.56	1463	652
60	68.27	725	794	92.16	983	794	138.97	1475	658
61	70.06	732	802	95.08	993	802	142.62	1489	664
62	71.70	737	810	97.31	1000	810	145.37	1500	670
63	73.47	743	818	99.72	1007	818	149.57	1512	675
64	75.20	748	826	102.06	1016	826	153.12	1522	681
65	76.97	754	832	104.46	1024	832	156.70	1535	686
66	78.72	760	840	106 03	1032	840	160.25	1548	692
67	80.51	766	848	109.21	1039	848	163.97	1559	698
68	82.33	772	857	111.84	1047	857	167.77	1571	703
69	83.84	777	865	114.47	1055	865	171.32	1582	709
70	85.98	783	873	116.75	1063	873	175.15	1594	714
71	87.74	788	880	119.23	1070	880	178.87	1605	720
72	89.76	794	888	121.82	1078	888	182.72	1616	726
73	91.60	799	895	124 29	1085	895	186.41	1627	732
74	93.51	805	904	126.90	1093	904	190.44	1639	738
75	95.43	810	910	129.52	1100	910	193.29	1650	743
76	97 35	816	917	132 07	1107	917	198.07	1660	750
77	99.26	821	925	134.73	1114	925	202.08	1671	755
78	101.17	826	933	137.38	1121	933	206.05	1682	760
79	103.15	832	940	139.98	1129	940	209.98	1693	766
80	105.10	837	947	142.64	1136	947	213.36	1705	771
81	107.07	842	954	145.34	1143	954	217.90	1715	776
82	109.03	847	961	148.07	1150	961	222.00	1725	782
83	111.10	852	968	150 80	1157	968	225.75	1735	787
84	113.21	858	975	153.69	1164	975	230.54	1746	793
85	115.16	863	982	156.28	1171	982	234.43	1756	798
86	117.07	868	988	158.87	1178	988	238.33	1766	803
87	119.24	873	995	161.82	1185	995	242.73	1777	809

Capacities Hunt-Francis Turbines

Head	18 Inch Wheel. 89 Square Inch Vent.			21 Inch Wheel. 124 Square Inch Vent.			24 Inch Wheel. 159 Square Inch Vent.		
	Horse Power.	Cu Ft. Min	Rev. Min.	Horse Power.	Cu. Ft. Min.	Rev. Min.	Horse Power.	Cu. Ft. Min.	Rev. Min.
4	3.68	595	134	5.13	829	122	6.58	1062	110
5	5.15	665	150	7.17	927	133	9.20	1188	117
6	6.77	738	165	9.44	1020	144	12.12	1301	124
7	8.52	787	176	11.90	1096	153	15.28	1406	130
8	10.41	841	189	14.54	1172	165	18.67	1503	141
9	12.46	892	201	17.35	1242	176	22.24	1593	151
10	14.60	941	213	20.36	1311	186	26.12	1681	160
11	16.81	986	226	23.46	1374	198	30.11	1762	170
12	19.18	1030	236	26.74	1435	207	34.30	1840	178
13	21.64	1072	246	30.22	1494	216	38.80	1916	186
14	24.19	1112	256	33.82	1549	225	43.46	1986	194
15	26.81	1152	266	37.31	1604	234	47.92	2057	202
16	29.52	1189	276	41.25	1656	242	52.99	2124	209
17	32.22	1226	286	45.21	1708	251	58.20	2189	216
18	35.27	1262	294	49.43	1759	258	63.59	2255	223
19	38.13	1297	302	53.25	1807	266	68.31	2317	230
20	41.16	1330	310	57.82	1853	273	74.49	2375	236
21	44.28	1363	319	61.88	1898	279	79.49	2434	240
22	47.47	1394	327	66.72	1942	287	85.97	2490	246
23	50.75	1423	335	71.28	1985	292	91.81	2547	250
24	54.12	1454	342	76.08	2028	299	98.05	2601	256
25	57.56	1484	351	80.93	2071	305	104.30	2657	260
26	61.00	1513	357	86.09	2111	311	111.18	2709	265
27	64.53	1542	364	90.46	2151	317	116.40	2760	270
28	68.22	1570	372	95.61	2191	323	123.00	2811	274
29	71.91	1598	379	100.14	2233	329	130.38	2869	279
30	75.60	1625	385	106.41	2267	335	137.23	2910	284
31	79.45	1652	390	111.35	2304	340	143.26	2957	289
32	82.82	1679	398	116.33	2342	345	149.85	3005	293
33	86.92	1705	403	121.99	2379	350	157.07	3053	298
34	91.02	1730	410	128.02	2413	356	165.03	3097	302
35	95.12	1756	418	133.38	2449	362	171.65	3142	307
36	99.22	1784	423	138.55	2486	367	177.89	3188	312
37	103.32	1809	429	144.33	2521	372	185.55	3232	316
38	107.42	1833	434	150.24	2554	377	193.06	3275	320
39	112.34	1857	439	156.55	2588	382	200.76	3318	325
40	116.44	1881	444	162.53	2620	387	208.62	3360	329
41	120.54	1904	449	168.57	2653	391	216.61	3401	333
42	125.46	1928	455	175.06	2686	396	224 67	3444	337
43	129.56	1950	460	181.16	2717	401	232.77	3484	342
44	132.15	1973	465	190.07	2749	408	237.87	3525	347
45	137.54	1996	470	196.29	2780	416	247.28	3565	352

Capacities Hunt-Francis Turbines

Head.	18 Inch Wheel. 89 Square Inch Vent.			21 Inch Wheel. 124 Square Inch Vent.			24 Inch Wheel. 159 Square Inch Vent.		
	Horse Power.	Cu Ft. Min	Rev Min	Horse Power.	Cu Ft. Min.	Rev. Min.	Horse Power.	Cu Ft Min.	Rev Min
46	144 00	2017	475	200.63	2810	422	257.25	3603	35
47	148.63	2039	480	207.08	2841	428	266.53	3643	36
48	153.56	2060	485	213.97	2871	434	273.36	3681	36
49	158.37	2081	490	220.65	2899	439	282.94	3717	36
50	163.08	2103	496	227 21	2930	444	291.34	3757	37
51	167.87	2123	502	233.90	2959	449	299.93	3794	37
52	172.97	2145	507	240.99	2988	454	309.03	3832	38
53	177 95	2164	513	247.93	3016	459	317.92	3869	38
54	182.90	2185	518	254.81	3044	463	326.72	3903	39
55	188.08	2205	524	262.06	3073	468	336.02	3938	39
56	193.32	2225	530	269.34	3100	473	345.37	3975	39
57	198 47	2245	536	276.50	3128	478	354.57	4012	40
58	203.72	2265	541	283.85	3156	483	363.94	4046	40
59	209.10	2285	547	291.34	3183	487	373.57	4082	41
60	214.39	2303	552	298.70	3209	491	383.01	4115	41
61	220.02	2326	558	306.54	3240	495	391.05	4155	41
62	225.19	2342	563	314.23	3262	499	402.27	4183	42
63	230.72	2360	568	321.46	3288	503	412.19	4217	42
64	235.62	2378	573	329.05	3315	507	421.94	4249	43
65	241.73	2398	578	336.79	3340	511	431.86	4283	43
66	247.11	2416	583	344 44	3367	515	441.66	4317	43
67	252.96	2435	588	352.43	3391	519	451.91	4349	44
68	258.79	2453	593	360.56	3417	521	462.27	4382	44
69	264.31	2471	598	368.29	3442	525	471.23	4414	44
70	270.19	2488	602	376.44	3467	529	482.50	4446	45
71	275.91	2506	607	384.42	3492	533	492.92	4477	45
72	281.88	2524	612	392.73	3516	537	500.42	4509	45
73	287.66	2541	617	400.77	3540	541	512.84	4539	46
74	293.67	2559	621	409.17	3565	544	524.66	4571	46
75	299.71	2576	626	417.57	3589	548	535.43	4601	46
76	305.60	2593	631	425.79	3612	552	545.97	4632	47
77	312 24	2610	635	434.23	3636	555	556.94	4662	47
78	317.85	2626	640	442.85	3659	558	567.85	4692	47
79	323.92	2643	645	451.29	3683	561	578.67	4722	48
80	330.07	2660	649	459.88	3707	565	589.68	4752	48
81	336.31	2677	654	468.57	3730	569	600.83	4782	48
82	342.46	2693	659	477.11	3752	572	611.82	4811	49
83	348.85	2709	664	486.03	3775	575	623.23	4840	49
84	355.65	2726	669	495.51	3798	578	635.37	4870	49
85	361.64	2742	673	503.80	3820	582	646.07	4899	50
86	367.65	2758	678	512.23	3843	586	656.82	4927	50
87	374.44	2774	683	521.60	3864	589	668.95	4956	51

Capacities Hunt-Francis Turbines

Head.	27 INCH WHEEL. 200 Square Inch Vent.			30 INCH WHEEL. 238 Square Inch Vent.			33 INCH WHEEL. 292 Square Inch Vent.		
	Horse Power.	Cu Ft. Min.	Rev. Min.	Horse Power.	Cu. Ft. Min.	Rev. Min.	Horse Power.	Cu. Ft. Min.	Rev. Min.
4	8.22	1336	96	9.86	1590	82	12.08	1951	75
5	11.48	1494	104	13.77	1778	90	16.87	2181	82
6	15.13	1636	111	18.14	1947	98	22.19	2389	89
7	19.07	1768	117	22.87	2104	104	27.99	2581	96
8	23.31	1890	126	27.95	2249	112	34.23	2759	103
9	27.77	2040	136	33.30	2385	121	40.79	2926	110
10	32.61	2114	144	39.10	2516	128	47.98	3087	117
11	37.59	2216	152	45.06	2637	134	55.07	3235	123
12	42.82	2314	160	51.35	2754	141	62.88	3378	129
13	48.44	2410	167	58.08	2868	148	71.13	3518	135
14	54.25	2498	173	65.05	2973	153	79.67	3647	141
15	59.84	2588	181	71.75	3080	160	87.87	3778	147
16	66.15	2672	188	79.32	3180	166	97.15	3891	153
17	72.66	2754	194	87.12	3277	172	106.70	4021	159
18	79.39	2836	200	95.19	3375	176	116.59	4141	164
19	85.51	2914	206	105.71	3468	182	125.75	4254	170
20	93.01	2988	212	111.52	3556	187	136.58	4362	174
21	99.24	3062	216	118.99	3644	191	145.74	4471	178
22	107.24	3132	221	128.38	3727	195	157.25	4573	183
23	114.62	3204	225	137.43	3813	200	168.32	4678	186
24	122.39	3272	230	146.73	3894	205	179.71	4777	189
25	130.21	3342	235	156.12	3976	210	191.22	4879	193
26	138.28	3408	240	165.38	4046	214	202.56	4976	197
27	144.32	3472	245	172.25	4132	218	212.41	5069	200
28	153.55	3536	249	184.10	4208	222	225.47	5163	204
29	162.77	3596	253	195.16	4279	227	239.03	5250	207
30	171.32	3660	258	205.42	4355	231	251.63	5344	210
31	178.85	3720	262	214.45	4427	235	262.66	5431	213
32	187.08	3780	266	224.31	4498	238	274.74	5519	217
33	196.09	3840	270	235.12	4570	242	287.98	5606	220
34	206.01	3896	275	247.00	4626	247	302.54	5688	224
35	214.21	3952	279	256.78	4703	250	314.50	5770	228
36	222.08	4010	283	266.27	4772	253	326.13	5855	232
37	231.64	4066	287	277.72	4839	256	340.15	5936	236
38	241.02	4120	291	288.99	4903	260	353.96	6015	240
39	250.00	4174	295	300.52	4967	263	368.07	6094	244
40	260.46	4226	299	312.30	5029	266	382.50	6170	247
41	270.47	4276	303	324.33	5091	269	397.17	6235	250
42	280.49	4310	307	336.32	5155	272	411.91	6314	254
43	290.60	4375	311	348.43	5215	275	426.75	6387	257
44	302.90	4434	315	356.08	5276	279	442.12	6474	261
45	312.91	4484	319	367.83	5336	284	456.82	6546	265

Capacities Hunt-Francis Turbines

Head.	36 Inch Wheel. 345 Square Inch Vent. Horse Power.	Cu. Ft. Min.	Rev. Min	39 Inch Wheel. 404 Square Inch Vent. Horse Power	Cu. Ft. Min.	Rev Min
4	14.30	2305	67	16.72	2699	61
5	19.97	2577	74	23.36	3018	68
6	26.24	2822	81	30.74	3305	75
7	33.12	3050	87	38.78	3578	81
8	40.52	3260	93	47.40	3818	87
9	48.27	3457	102	56.47	4048	93
10	56.86	3647	107	66.62	4270	99
11	65.32	3823	112	76.42	4476	104
12	74.41	3992	118	87.13	4674	109
13	84.18	4157	124	98.50	4868	115
14	94.30	4309	129	110.32	5046	120
15	104.00	4464	133	121.72	5228	124
16	114.99	4609	139	134.54	5397	129
17	126.28	4751	143	147.75	5563	133
18	137.99	4892	147	161.45	5729	137
19	148.79	5027	151	174.14	5886	140
20	161.65	5154	156	188.63	6036	145
21	172.49	5282	160	201.63	6185	148
22	186.11	5403	164	217.14	6327	152
23	199.21	5527	168	232.47	6472	156
24	212.69	5644	172	247.78	6609	159
25	226.32	5765	176	264.35	6751	163
26	239.74	5879	179	281.28	6884	166
27	252.58	5989	182	294.93	7013	169
28	266.85	6100	186	311.18	7143	173
29	282.90	6203	189	329.37	7264	176
30	297.83	6314	193	348.22	7393	179
31	310.86	6417	196	362.26	7514	182
32	325.17	6521	200	379.31	7636	186
33	340.84	6624	203	397.62	7757	189
34	358.09	6721	206	416.50	7870	192
35	372.23	6817	209	434.30	7983	195
36	385.99	6917	212	451.45	8100	197
37	402.58	7014	215	470.85	8213	199
38	418.92	7107	217	489.95	8322	201
39	435.62	7200	220	509.47	8431	204
40	452.70	7290	223	529.46	8540	206
41	470.00	7380	226	549.69	8640	208
42	487.50	7473	229	570.16	8741	211
43	505.08	7559	232	590.62	8841	214
44	516.16	7649	235	611.42	8957	217
45	533.14	7735	238	632.05	9058	220

Capacities Hunt-Francis Turbines

Head	42 INCH WHEEL. 462 Square Inch Vent.			45 INCH WHEEL. 506 Square Inch Vent.		
	Horse Power.	Cu Ft. Min.	Rev. Min.	Horse Power.	Cu. Ft. Min.	Rev. Min.
4	19.14	3087	56	20.70	3380	51
5	26.76	3452	63	28.92	3780	58
6	35.25	3771	69	38.10	4139	65
7	44.43	4086	75	47.99	4473	70
8	54.27	4368	80	58.64	4782	75
9	64.67	4632	85	69.92	5070	80
10	76.27	4886	91	82.02	5348	86
11	87.53	5122	96	94.55	5606	90
12	99.84	5348	101	107.81	5854	95
13	112.81	5570	106	121.62	6097	99
14	126.35	5773	110	136.17	6320	103
15	139.44	5977	114	150.59	6548	107
16	154.08	6176	118	166.84	6760	111
17	169.21	6365	123	182.44	6968	115
18	184.91	6555	126	199.00	7175	118
19	199.49	6735	129	215.62	7372	122
20	215.62	6902	133	233.28	7560	125
21	230.77	7073	136	249.66	7747	128
22	248.18	7235	140	268.50	7924	131
23	265.73	7401	143	287.49	8106	134
24	282.88	7558	147	306.04	8278	137
25	302.39	7720	150	327.07	8455	140
26	320.83	7872	153	347.10	8622	143
27	337.28	8020	157	364.88	8784	147
28	355.51	8168	160	384.69	8946	150
29	375.83	8307	163	406.60	9098	153
30	398.61	8455	165	431.24	9260	155
31	413.66	8593	168	447.54	9412	158
32	433.45	8732	171	468.94	9563	161
33	454.41	8870	174	491.60	9715	163
34	474.91	9000	176	513.82	9857	165
35	496.37	9129	178	537.02	9999	167
36	516.90	9263	180	559.22	10145	169
37	539.11	9392	182	583.26	10287	171
38	560.99	9517	185	606.92	10424	174
39	583.36	9642	187	630.34	10560	176
40	606.23	9762	189	655.87	10692	178
41	629.39	9882	191	680.93	10822	180
42	652.82	10007	193	707.04	10962	182
43	676.17	10122	195	731.76	11082	185
44	691.17	10242	197	757.02	11217	187
45	714.02	10358	199	781.86	11345	190

Capacities Hunt-Francis Turbines

Head.	48 Inch Wheel. 550 Square Inch Vent.			51 Inch Wheel. 645 Square Inch Vent.		
	Horse Power.	Cu. Ft Min.	Rev. Min.	Horse Power.	Cu. Ft. Min.	Rev. Min.
4	21.00	3674	46	26.32	4309	43
5	31.05	4109	52	36.90	4818	50
6	40.90	4499	60	48.46	5376	57
7	51.52	4862	66	61.09	5702	63
8	62.97	5196	71	74.25	6095	66
9	75.07	5511	75	89.05	6463	71
10	88.06	5814	81	104.30	6818	76
11	101.14	6094	85	120.37	7147	81
12	115.52	6364	89	137.10	7463	85
13	130.52	6628	93	154.81	7772	88
14	146.19	6870	97	172.69	8054	91
15	161.66	7117	100	191.88	8346	94
16	178.68	7348	103	210.74	8617	98
17	195.86	7574	107	231.24	8882	104
18	213.67	7799	111	251.74	9146	108
19	231.42	8014	114	273.06	9398	112
20	250.45	8217	117	295.20	9636	114
21	268.03	8421	120	317.36	9875	116
22	288.25	8613	122	340.30	10101	118
23	308.64	8811	125	364.08	10333	121
24	328.55	8998	128	387.86	10552	124
25	341.85	9191	131	412.46	10778	126
26	372.63	9372	134	437.06	10991	129
27	391.73	9548	137	462.48	11197	131
28	412.93	9724	140	488.72	11404	133
29	436.50	9889	142	514.96	11597	136
30	463.80	10065	145	541.20	11804	138
31	480.45	10230	147	569.08	11997	141
32	503.43	10395	150	594.96	12191	143
33	527.76	10560	152	624.84	12384	145
34	551.58	10714	154	653.54	12464	147
35	576.52	10868	156	683.06	12745	150
36	603.23	11028	158	712.58	12932	152
37	626.15	11182	160	742.10	13113	153
38	651.56	11330	162	772.44	13287	155
39	678.34	11479	164	802.78	13461	156
40	704.11	11622	166	833.94	13628	158
41	739.02	11770	168	874.09	13797	160
42	758.22	11913	170	906.48	13971	162
43	785.58	12051	172	938.10	14133	164
44	812.70	12194	174	967.50	14300	166
45	839.53	12331	176	995.48	14454	168

Capacities Hunt-Francis Turbines

Head.	54 INCH WHEEL. 740 Square Inch Vent.			57 INCH WHEEL. 886 Square Inch Vent.		
	Horse Power.	Cu. Ft. Min.	Rev. Min.	Horse Power.	Cu. Ft. Min.	Rev. Min.
4	30.67	4943	44	34.65	5584	39
5	42.84	5528	49	48.40	6245	44
6	56.44	6053	54	63.76	6838	50
7	71.13	6542	60	80.36	7390	56
8	86.95	6993	64	98.21	7900	60
9	103.54	7415	68	116.97	8377	64
10	121.58	7822	72	137.36	8836	68
11	140.13	8199	76	158.31	9263	71
12	159.67	8562	80	180.39	9672	75
13	180.56	8917	83	204.00	10074	78
14	202.26	9243	86	228.50	10447	82
15	223.08	9576	89	252.02	10818	84
16	246.66	9886	92	278.66	11169	87
17	270.88	10190	95	306.02	11512	90
18	295.99	10493	98	334.39	11854	93
19	319.36	10782	101	360.79	12180	95
20	346.73	11056	103	391.71	12490	97
21	369.99	11329	106	417.99	12798	100
22	399.20	11588	108	450.99	13091	103
23	427.31	11854	111	482.75	13392	106
24	456.23	12106	116	515.40	13676	109
25	485.44	12365	117	548.43	13951	111
26	514.23	12609	119	580.90	14245	113
27	541.78	12846	121	612.06	14512	115
28	572.36	13083	124	646.09	14780	117
29	601.88	13305	126	678.40	15031	119
30	635.96	13542	128	715.28	15299	121
31	666.50	13674	130	747.97	15504	123
32	697.00	13986	132	782.25	15800	125
33	731.03	14208	134	820.24	16051	127
34	767.09	14415	137	861.32	16285	130
35	797.86	14622	139	895.46	16519	132
36	827.93	14837	141			
37	863.52	15044	143			
38	898.55	15244	145			
39	934.39	15444	147			
40	971.00	15636	148			
41	1008.14	15829	150			
42	1045.66	16028	151			
43	1083.37	16213	152			
44	1107.11	16406	153			
45	1142.91	16591	155			

Capacities Hunt-Francis Turbines

Head.	60 INCH WHEEL. 932 Square Inch Vent.			66 INCH WHEEL. 1035 Square Inch Vent.		
	Horse Power.	Cu. Ft. Min.	Rev. Min.	Horse Power.	Cu. Ft. Min	Rev Min.
4	38.63	6226	34	42.90	6914	29
5	53.96	6962	40	59.93	7731	35
6	71.08	7624	46	78.94	8466	41
7	89.59	8239	52	99.49	9149	48
8	109.48	8807	56	121.58	9781	51
9	130.41	9339	60	144.82	10371	55
10	153.15	9851	64	170.14	10940	58
11	176.49	10327	66	196.00	11468	61
12	201.11	10783	70	223.33	11975	64
13	227.45	11231	74	252.58	12472	68
14	254.74	11651	77	282.90	12927	71
15	280.96	12060	80	312.01	13393	73
16	310.66	12452	83	344.99	13828	76
17	341.17	12834	86	378.84	14252	79
18	372.79	13216	88	413.99	14676	81
19	402.22	13579	90	446.67	15080	83
20	436.69	13924	92	484.96	15463	86
21	465.99	14268	95	517 49	15846	88
22	502.78	14595	98	558.35	16208	90
23	538.19	14930	100	595.67	16580	92
24	574.57	15247	103	638.11	16932	94
25	611.42	15537	105	678.96	17294	97
26	647.58	15881	107	719.23	17636	99
27	682.35	16179	109	757.81	17967	101
28	719.82	16478	111	790.88	18299	103
29	754.92	16757	113	835.35	18609	105
30	794.61	17056	115	879.41	18941	107
31	829.44	17335	117	920.97	19251	109
32	867.51	17615	119	963.09	19561	111
33	909.46	17894	121	1008.26	19872	113
34	955.55	18155	123	1054.10	20162	115
35	993.06	18416	125	1101.11	20452	117

If desired to ascertain the power developed, and the amount of water used under higher heads than indicated in the foregoing tables, the following may be used as data :—

The quantity of water increases as the square root of the head. If the head is increased four times, on the same wheel, proximately twice the quantity of water will be discharged, but the power will be increased eight times.

THE SIZE SPACE A TURBINE WHEEL OCCUPIES

TABLE OF DIMENSIONS HUNT-McCORMICK TURBINES

Size of Wheel.	Diam. of hole to be made through floor of flume.	Diam. of top flange on draft-tube.	Size of flume inside of planking.	Depth of draft-tube.	Size of Shaft.	Length of Shaft from flume floor.
9 inch.	1 ft. 4 in.	1 ft. $10\frac{1}{2}$ in.	2 ft. 3 in.	7 inch.	$1\frac{13}{20}$ in.	1 ft. $11\frac{1}{4}$ in.
12 inch.	1 ft. 8 in.	1 ft. $1\frac{1}{4}$ in.	3 ft.	8 inch.	$2\frac{3}{20}$ in.	2 ft. $11\frac{5}{16}$ in.
15 inch.	2 ft. 1 in.	2 ft. $5\frac{3}{4}$ in.	3 ft. 9 in.	10 inch.	$2\frac{4}{10}$ in.	3 ft. $5\frac{5}{8}$ in.
18 inch.	2 ft. 4 in.	2 ft. 8 in.	4 ft. 6 in.	11 inch.	$2\frac{9}{10}$ in.	3 ft. $8\frac{7}{8}$ in.
21 inch.	2 ft. 8 in.	3 ft. $1\frac{1}{4}$ in.	5 ft. 3 in.	13 inch.	$3\frac{3}{20}$ in.	4 ft. $2\frac{5}{16}$ in.
24 inch.	3 ft. $\frac{1}{2}$ in.	3 ft. 4 in.	6 ft.	14 inch.	$3\frac{4}{10}$ in.	4 ft. $7\frac{5}{16}$ in.
27 inch.	3 ft. 5 in.	3 ft. $9\frac{7}{8}$ in.	6 ft. 9 in.	16 inch.	$3\frac{13}{20}$ in.	4 ft. $10\frac{3}{16}$ in.
30 inch.	3 ft. 9 in.	4 ft. $3\frac{5}{8}$ in.	7 ft. 6 in.	18 inch.	$3\frac{9}{10}$ in.	5 ft. $3\frac{5}{8}$ in.
33 inch.	4 ft. 2 in.	4 ft. 7 in.	8 ft. 3 in.	19 inch.	$4\frac{3}{20}$ in.	6 ft. $1\frac{3}{4}$ in.
36 inch.	4 ft. 6 in.	5 ft. $\frac{1}{8}$ in.	9 ft.	23 inch.	$4\frac{9}{10}$ in.	6 ft. 6 in.
39 inch.	4 ft. $10\frac{1}{2}$ in.	5 ft. 5 in.	9 ft. 9 in.	24 inch.	$5\frac{13}{20}$ in.	6 ft. 10 in.
42 inch.	5 ft. $3\frac{1}{2}$ in.	5 ft. 10 in.	10 ft. 6 in.	26 inch.	$5\frac{9}{10}$ in.	7 ft. $1\frac{5}{8}$ in.
45 inch.	5 ft. $7\frac{1}{2}$ in.	6 ft. 3 in.	11 ft. 3 in.	27 inch.	$6\frac{3}{20}$ in.	7 ft. $6\frac{11}{16}$ in.
48 inch.	6 ft. 11 in.	6 ft. $6\frac{1}{8}$ in.	12 ft.	29 inch.	$6\frac{4}{10}$ in.	8 ft. $\frac{7}{16}$ in.
52 inch.	6 ft. $3\frac{1}{2}$ in.	7 ft. $\frac{1}{4}$ in.	12 ft. 9 in.	31 inch.	$7\frac{1}{2}$ in.	8 ft. $9\frac{13}{16}$ in.
54 inch.	6 ft. 8 in.	7 ft. $5\frac{3}{4}$ in.	13 ft. 6 in.	33 inch.	$7\frac{13}{20}$ in.	9 ft. $3\frac{13}{16}$ in.
57 inch.	7 ft.	7 ft. $10\frac{1}{2}$ in.	14 ft. 3 in.	34 inch.	$7\frac{9}{10}$ in.	9 ft. 6 in.
60 inch.	7 ft. 4 in.	8 ft. $1\frac{1}{4}$ in.	15 ft.	36 inch.	$8\frac{3}{20}$ in.	9 ft. $11\frac{13}{16}$ in.
66 inch.	8 ft.	8 ft. $10\frac{1}{4}$ in.	16 ft. 6 in.	40 inch.	$8\frac{9}{10}$ in.	10 ft. 6 in.

Capacities Hunt-McCormick Turbines

Head.	9 Inch Wheel.			12 Inch Wheel.			15 Inch Wheel.		
	Horse Power.	Cu Ft. Min.	Rev. Min.	Horse Power.	Cu. Ft. Min.	Rev. Min.	Horse Power.	Cu. Ft. Min.	Rev. Min.
5	1.5	204	297	2.7	355	223	4.3	566	178
6	2.0	223	325	3.5	389	244	5.6	620	195
7	2.6	241	351	4.4	420	263	7.1	670	211
8	3.1	258	375	5.4	449	282	8.7	716	225
9	3.7	273	398	6.5	476	299	10.3	760	239
10	4.4	288	420	7.6	502	315	12.1	801	252
11	5.0	302	440	8.8	527	330	14.0	840	264
12	5.7	316	460	10.0	550	345	15.9	877	276
13	6.5	329	479	11.2	573	359	17.9	913	287
14	7.2	341	497	12.6	594	373	20.0	947	298
15	8.0	353	514	13.9	615	386	22.2	981	308
16	8.8	365	531	15.4	635	398	24.5	1013	319
17	9.7	376	547	16.8	655	411	26.8	1044	328
18	10.5	387	563	18.3	674	422	29.2	1074	338
19	11.4	397	579	19.9	692	434	31.7	1104	347
20	12.3	408	594	21.5	710	445	34.2	1132	356
21	13.3	418	608	23.1	728	456	36.8	1160	365
22	14.2	428	623	24.8	745	467	39.5	1188	374
23	15.2	437	637	26.5	762	477	42.2	1214	382
24	16.2	447	650	28.2	778	488	45.0	1240	390
25	17.2	456	664	30.0	794	498	47.8	1266	398
26	18.3	465	677	31.8	810	508	50.7	1291	406
27	19.3	474	690	33.7	825	517	53.7	1316	414
28	20.4	482	702	35.6	840	527	56.7	1340	421
29	21.5	491	715	37.5	855	536	59.8	1364	429
30	22.6	499	727	39.4	870	545	62.9	1387	436
31	23.8	508	739	41.4	884	554	66.0	1410	443
32	24.9	516	751	43.4	898	563	69.3	1432	451
33	26.1	524	763	45.5	912	572	72.5	1455	458
34	27.3	532	774	47.6	926	581	75.9	1476	464
35	28.5	539	785	49.7	940	589	79.2	1498	471
36	29.8	547	796	51.8	953	597	82.6	1519	478
37	31.0	554	807	54.0	966	606	86.1	1540	484
38	32.3	562	818	56.2	979	614	89.6	1561	491
39	33.5	569	829	58.4	992	622	93.2	1581	497
40	34.8	577	840	60.7	1004	630	96.8	1601	504

Capacities Hunt-McCormick Turbines

Head.	18 Inch Wheel.			21 Inch Wheel			24 Inch Wheel.		
	Horse Power.	Cu. Ft. Min.	Rev. Min.	Horse Power.	Cu. Ft. Min.	Rev. Min	Horse Power.	Cu. Ft. Min.	Rev. Min.
5	6.3	828	144	8.9	1172	137	11.7	1547	113
6	8.2	908	158	11.6	1283	150	15.4	1695	124
7	10.4	980	170	14.7	1386	162	19.4	1831	134
8	12.7	1048	182	17.9	1482	173	23.7	1957	143
9	15.1	1111	193	21.4	1572	184	28.2	2076	152
10	17.7	1172	203	25.0	1657	194	33.1	2188	160
11	20.4	1229	213	28.9	1738	203	38.1	2295	168
12	23.3	1283	223	32.9	1815	212	43.5	2397	175
13	26.2	1336	232	37.1	1889	221	49.0	2495	182
14	29.3	1386	241	41.5	1960	229	54.8	2589	189
15	32.5	1435	249	46 0	2029	237	60.7	2680	196
16	35.8	1482	257	50.7	2096	245	66.9	2768	202
17	39.2	1528	265	55.5	2160	253	73.3	2853	208
18	42.8	1572	273	60.5	2223	260	79.8	2936	214
19	46.4	1615	280	65.6	2284	267	86.6	3016	220
20	50.1	1657	288	70.8	2343	274	93.5	3095	226
21	53.9	1698	295	76.2	2401	281	100.6	3171	232
22	57.8	1738	302	81.7	2457	287	107.9	3246	237
23	61.8	1777	309	87.3	2513	294	115.3	3318	242
24	65.8	1815	315	93.1	2567	300	122.9	3390	248
25	70.0	1852	322	99.0	2620	306	130.7	3460	253
26	74.2	1889	328	105.0	2672	312	138.6	3528	258
27	78.5	1925	334	111.1	2722	318	146.7	3595	263
28	82.9	1960	340	117.3	2772	324	154.9	3661	267
29	87.4	1995	346	123.6	2821	330	163.3	3726	272
30	92.0	2029	352	130.1	2870	336	171.8	3790	277
31	96.6	2063	358	136.6	2917	341	180.5	3853	281
32	101.3	2096	364	143.3	2964	347	189.3	3914	286
33	106.1	2128	370	150.1	3010	352	198.2	3975	290
34	111.0	2160	375	157.0	3055	357	207.3	4035	295
35	115.9	2192	381	163.9	3100	362	216.5	4094	299
36	120.9	2223	386	171.0	3144	368	225.8	4152	303
37	126.0	2254	391	178.2	3187	373	235.3	4209	307
38	131.1	2284	397	185.5	3230	378	244.9	4265	312
39	136.4	2314	402	192.8	3272	383	254.7	4321	316
40	141.6	2343	407	200.3	3314	387	264.5	4376	320

Capacities Hunt-McCormick Turbines

Head.	27 Inch Wheel.			30 Inch Wheel.			33 Inch Wheel.		
	Horse Power.	Cu. Ft. Min.	Rev Min.	Horse Power.	Cu Ft. Min.	Rev. Min.	Horse Power.	Cu. Ft. Min.	Rev. Min.
5	14.8	1960	106	17.8	2361	93	19.8	2626	81
6	19.5	2147	116	23.4	2686	102	26.1	2876	89
7	24.5	2319	125	29.5	2793	110	32.9	3107	96
8	30.0	2479	134	36.1	2986	118	40.2	3321	102
9	35.8	2629	142	43.1	3167	125	47.9	3523	109
10	41.9	2771	149	50.4	3338	132	56.1	3713	114
11	48.3	2906	157	58.2	3501	138	64.7	3895	120
12	55.0	3036	164	66.3	3657	144	73.8	4068	125
13	62.1	3160	170	74.8	3806	150	83.2	4234	131
14	69.4	3279	177	83.6	3950	156	92.9	4394	135
15	76.9	3394	183	92.7	4089	161	103.1	4548	140
16	84.7	3505	189	102.1	4223	167	113.6	4697	145
17	92.8	3613	195	111.8	4353	172	124.4	4842	149
18	101.1	3718	200	121.8	4479	177	135.5	4982	154
19	109.7	3820	206	132.1	4602	182	147.0	5119	158
20	118.4	3919	211	142.7	4721	186	158.7	5252	162
21	127.4	4016	217	153.5	4838	191	170.8	5381	166
22	136.6	4110	222	164.6	4952	195	183.1	5508	170
23	146.1	4203	227	176.0	5063	200	195.7	5632	174
24	155.7	4293	231	187.6	5172	204	208.6	5753	177
25	165.5	4382	236	199.4	5278	208	221.8	5871	181
26	175.6	4468	241	211.5	5383	212	235.2	5988	185
27	185.8	4554	245	223.8	5486	216	248.9	6102	188
28	196.2	4637	250	236.3	5586	220	262.9	6214	192
29	206.8	4719	254	249.1	5685	224	277.1	6324	195
30	217.6	4800	259	262.1	5782	228	291.6	6432	198
31	228.6	4879	263	275.3	5878	232	306.3	6538	202
32	239.7	4957	267	288.8	5972	236	321.2	6643	205
33	251.0	5034	271	302.4	6064	239	336.4	6746	208
34	262.5	5110	275	316.3	6156	243	351.8	6847	211
35	274.2	5184	280	330.3	6246	246	367.4	6947	214
36	286.0	5258	283	344.6	6334	250	383.3	7046	217
37	298.0	5331	287	359.0	6421	253	399.4	7143	220
38	310.2	5402	291	373.7	6508	257	415.7	7239	223
39	322.5	5473	295	388.5	6593	260	432.2	7333	226
40	335.0	5542	299	403.6	6677	263	448.9	7427	229

Capacities Hunt-McCormick Turbines

Head.	36 Inch Wheel.			39 Inch Wheel.		
	Horse Power.	Cu. Ft. Min.	Rev. Min.	Horse Power.	Cu. Ft. Min.	Rev. Min.
5	25.1	3316	79	29.4	3898	69
6	32.9	3632	87	38.7	4270	76
7	41.5	3923	94	48.8	4612	82
8	50.7	4194	100	59.6	4930	87
9	60.5	4449	106	71.1	5229	93
10	70.9	4689	112	83.3	5512	98
11	81.7	4918	118	96.1	5781	103
12	93.1	5137	123	109.5	6038	107
13	105.0	5347	128	123.5	6285	111
14	117.4	5548	133	138.0	6522	116
15	130.2	5743	137	153.0	6751	120
16	143.4	5931	142	168.6	6972	124
17	157.1	6114	146	184.6	7187	127
18	171.1	6291	150	201.1	7395	131
19	185.6	6464	154	218.1	7598	135
20	200.4	6632	158	235.6	7795	138
21	215.6	6795	162	253.5	7988	142
22	231.2	6955	166	271.8	8176	145
23	247.2	7112	170	290.5	8359	148
24	263.4	7265	174	309.7	8539	151
25	280.1	7414	177	329.2	8715	155
26	297.1	7561	181	349.2	8888	158
27	314.4	7705	184	369.5	9057	161
28	332.0	7847	187	390.2	9223	164
29	349.9	7985	191	411.3	9387	166
30	368.2	8122	194	432.8	9547	169
31	386.7	8256	197	454.6	9705	172
32	405.6	8388	200	476.8	9860	175
33	424.8	8518	204	499.3	10013	178
34	444.2	8646	207	522.2	10164	180
35	464.0	8773	210	545.4	10312	183
36	484.0	8897	213	568.9	10459	186
37	504.3	9020	216	592.8	10603	188
38	524.9	9141	218	617.0	10745	191
39	545.7	9260	221	641.5	10885	193
40	566.9	9378	224	666.3	11024	196

Capacities Hunt-McCormick Turbines

Head.	42 Inch Wheel.			45 Inch Wheel.		
	Horse Power.	Cu. Ft. Min.	Rev. Min.	Horse Power.	Cu. Ft. Min.	Rev. Min.
5	36.2	4786	67	38.5	5096	61
6	47.5	5242	74	50.6	5582	67
7	59.9	5662	80	63.8	6030	72
8	73.2	6053	85	77.9	6446	77
9	87.3	6421	90	93.0	6837.	82
10	102.3	6768	95	108.9	7207	87
11	118.0	7098	100	125.6	7558	91
12	134.4	7414	104	143.1	7894	95
13	151.6	7717	108	161.4	8217	99
14	169.4	8008	112	180.4	8527	102
15	187.9	8289	116	200.1	8826	106
16	207.0	8561	120	220.4	9116	109
17	226.7	8824	124	241.4	9396	113
18	247.0	9080	128	263.0	9669	116
19	267.8	9329	131	285.2	9934	119
20	289.3	9571	134	308.0	10192	122
21	311.2	9808	138	331.4	10443	125
22	333.7	10038	141	355.3	10689	128
23	356.7	10264	144	379.8	10929	131
24	380.2	10485	147	404.9	11164	134
25	404.2	10701	150	430.5	11395	137
26	428.7	10913	153	456.5	11620	139
27	453.7	11121	156	483.1	11842	142
28	479.1	11325	159	510.2	12059	145
29	505.0	11525	162	537.8	12272	147
30	531.4	11722	165	565.8	12482	150
31	558.2	11916	167	594.4	12689	152
32	585.4	12107	170	623.4	12892	155
33	613.1	12294	173	652.8	13091	157
34	641.1	12479	175	682.7	13288	160
35	669.6	12661	178	713.0	13482	162
36	698.5	12841	180	743.8	13674	164
37	727.8	13018	183	775.2	13862	166
38	757.5	13193	185	806.7	14048	169
39	787.6	13365	188	838.7	14232	171
40	818.1	13536	190	871.2	14413	173

Capacities Hunt-McCormick Turbines

Head.	48 Inch Wheel. Horse Power.	48 Inch Wheel. Cu. Ft. Min.	48 Inch Wheel. Rev. Min.	51 Inch Wheel. Horse Power.	51 Inch Wheel. Cu. Ft. Min.	51 Inch Wheel. Rev. Min.
5	43.4	5749	55	49.5	6545	56
6	57.1	6298	60	65.0	7170	61
7	72.0	6802	65	81.9	7745	66
8	87.9	7272	70	100.1	8279	70
9	104.9	7713	74	119.4	8782	75
10	122.9	8130	78	139.9	9257	79
11	141.7	8527	82	161.4	9708	82
12	161.5	8906	85	183.9	10140	86
13	182.1	9270	89	207.3	10554	90
14	203.5	9620	92	231.7	10952	93
15	225.7	9958	95	257.0	11337	96
16	248.6	10284	98	283.1	11709	99
17	272.3	10601	102	310.0	12069	103
18	296.7	10908	104	337.8	12419	106
19	321.8	11207	107	366.3	12759	108
20	347.5	11498	110	395.6	13091	111
21	373.9	11782	113	425.7	13414	114
22	400.9	12059	115	456.4	13730	117
23	428.5	12330	118	487.9	14038	119
24	456.8	12595	121	520.0	14340	122
25	485.6	12855	123	552.9	14636	124
26	515.0	13110	126	586.4	14926	127
27	545.0	13360	128	620.5	15210	129
28	575.6	13605	130	655.3	15489	132
29	606.7	13845	133	690.8	15763	134
30	630.4	14082	135	726.8	16033	136
31	670.5	14315	137	763.4	16298	138
32	703.3	14544	139	800.7	16559	141
33	736.5	14769	141	838.5	16815	143
34	770.2	14992	144	876.9	17068	145
35	804.4	15210	146	915.9	17317	147
36	839.2	15426	148	955.4	17363	149
37	874.4	15639	150	995.5	17805	151
38	910.0	15849	152	1036.1	18044	153
39	946.2	16056	154	1077.3	18280	155
40	982.8	16261	156	1119.0	18513	157

Capacities Hunt-McCormick Turbines

Head.	54 Inch Wheel.			57 Inch Wheel.		
	Horse Power.	Cu. Ft. Min.	Rev. Min.	Horse Power.	Cu. Ft. Min.	Rev. Min.
5	55.4	7338	51	65.3	8646	50
6	72.9	8038	56	85.9	9472	55
7	91.8	8682	60	108.2	10231	59
8	112.2	9282	64	132.2	10937	63
9	133.9	9845	68	157.8	11601	67
10	156.8	10378	72	184.8	12228	70
11	180.9	10884	76	213.2	12825	74
12	206.1	11368	79	242.9	13395	77
13	232.4	11832	82	273.9	13942	80
14	259.8	12279	85	300.1	14468	83
15	288.1	12710	88	330.4	14976	86
16	317.4	13127	91	374.0	15467	89
17	347.6	13531	94	409.6	15943	92
18	378.7	13923	97	446.2	16406	94
19	410.7	14304	99	483.9	16855	97
20	443.5	14676	102	522.6	17293	100
21	477.2	15038	105	562.3	17720	102
22	511.7	15392	107	602.9	18137	104
23	547.0	15738	109	644.5	18545	107
24	583.0	16077	112	687.0	18944	109
25	619.8	16408	114	730.4	19334	111
26	657.4	16733	116	774.6	19717	113
27	695.7	17052	119	819.7	20093	116
28	734.7	17365	121	865.7	20461	118
29	774.4	17672	123	912.5	20824	120
30	814.8	17974	125	960.1	21179	122
31	855.9	18272	127	1008.5	21530	124
32	897.6	18564	129	1057.7	21874	126
33	940.0	18852	131	1107.6	22213	128
34	983.1	19135	133	1158.4	22547	130
35	1026.8	19415	135	1209.9	22876	132
36	1071.1	19690	137	1262.1	23201	134
37	1116.0	19962	139	1315.0	23521	135
38	1161.6	20230	141	1368.7	23837	137
39	1207.7	20494	142	1423.1	24148	139
40	1254.5	20755	144	1478.2	24456	141

Pressure of Water at Different Elevations

Feet Head	Equals Pressure per Square Inch	Feet Head	Equals Pressure per Square Inch
1	(0.43 0.34	130	56.31
5	2.16	135	58.48
10	4.33	140	60.64
15	6.49	145	62.81
20	8.66	150	64.97
25	10.82	155	67.14
30	12.99	160	69.31
35	15.16	165	71.47
40	17.32	170	73.64
45	19.49	175	75.80
50	21.65	180	77.97
55	23.82	185	80.14
60	25.99	190	82.30
65	28.15	195	84.47
70	30.32	200	86.63
75	32.48	205	88.80
80	34.65	210	90.96
85	36.82	215	93.14
90	38.98	220	95.30
95	41.15	225	97.49
100	43.31	230	99.63
105	45.48	235	101.79
110	47.64	240	103.96
115	49.81	245	106.13
120	51.98	250	108.29
125	54.15	255	110.46

1 ft. head corresponds to 0.434 lbs. per sq. inch

1 lb. per sq. inch corresponds to 2.304 ft. head.

Weir Table

INCHES	0	1-8	2-8	3-8	4-8	5-8	6-8	7-8
0	0.	0.02	0.05	0.09	0.14	0.20	0.26	0.33
1	0.40	0.48	0.56	0.65	0.74	0.83	0.93	1.03
2	1.14	1.24	1.35	1.47	1.58	1.71	1.82	1.96
3	2.08	2.21	2.35	2.48	2.63	2.76	2.90	3.06
4	3.20	3.36	3.51	3.67	3.82	3.98	4.15	4.31
5	4.48	4.65	4.81	4.99	5.16	5.35	5.52	5.71
6	5.89	6.06	6.26	6.44	6.64	6.83	7.01	7.22
7	7.41	7.62	7.82	8.03	8.23	8.42	8.64	8.85
8	9.07	9.27	9.48	9.71	9.92	10.15	10.36	10.60
9	10.81	11.03	11.27	11.49	11.74	11.96	12.18	12.43
10	12.66	12.91	13.14	13.39	13.63	13.86	14.12	14.36
11	14.62	14.86	15.10	15.37	15.61	15.88	16.13	16.40
12	16.65	16.90	17.18	17.43	17.71	17.97	18.22	18.51
13	18.77	19.05	19.31	19.60	19.87	20.13	20.43	20.69
14	20.99	21.26	21.53	21.83	22.11	22.41	22.68	22.99
15	23.27	23.55	23.86	24.14	24.45	24.74	25.02	25.34
16	25.62	25.94	26.23	26.55	26.85	27.14	27.46	27.76
17	28.08	28.38	28.68	29.01	29.31	29.64	29.95	30.28
18	30.59	30.89	31.23	31.54	31.88	32.19	32.50	32.85
19	33.16	33.51	33.82	34.17	34.49	34.81	35.16	35.48
20	35.84	36.16	36.48	36.84	37.17	37.53	37.85	38.22
21	38.55	38.88	39.24	39.57	39.94	40.28	40.61	40.98
22	41.32	41.69	42.03	42.41	42.75	43.09	43.47	43.81
23	44.19	44.54	44.89	45.27	45.62	46.00	46.35	46.74
24	47.09	47.45	47.84	48.19	48.58	48.94	49.30	49.69

For measuring large streams, find the average velocity of the whole stream in feet per minute and the cross section in square feet. By multiplying these two amounts, the cubic feet flow of water per minute in the stream will be found. The velocity can be approximated by throwing light floating bodies into the middle of the stream and noting the time these bodies are passing the distance measured between two points. This distance should be taken where the flow is most even and uniform. The mean velocity of the stream will be about 83 per cent of the velocity of the surface near the centre of the stream.

Capacities and Diameters of Pipe

Doubling the diameter of a pipe increases its capacity four times.

Circular apertures are most effective for discharging water since they have less frictional surface for the same area. The area of a circular aperture is found by multiplying the square of the diameter by .7854.

To find the velocity in feet per minute necessary to discharge a given volume of water in a given time, multiply the number of cubic feet of water by 144, and divide the product by the area of the pipe in inches.

The time occupied in discharging equal quantities of water under equal heads through pipes of equal lengths will be different in varying forms and proportionately as follows: Have a straight line 90: Have a true curve 100: and have a right angle 140.

To find the horse power necessary to elevate the water to a given height, multiply the total weight of column of water in pounds by the velocity per minute in feet, and divide the product by 33-1000. An allowance of 25 per cent should be added for friction, etc.

To find the area of a required pipe, the volume and velocity of water being given, multiply the number of cubic feet of water by 144 and divide the product by the velocity in feet per minute. The area being found, the diameter of pipe is readily figured.

Friction of liquids in pipes increases as the square of their velocity.

Loss of Head in One Hundred Feet Length of Pipe at Different Velocities

Diameter of Pipe	Cubic feet per minute at one foot per second velocity	1 Foot per Second	1 ½ Ft. per Second	2 Feet per Second	3 Feet per Second	4 Feet per Second	5 Feet per Second	6 Feet per Second	7 Feet per Second
3	2.95	.186	.476	.700	1.507	2.600	3.937	5.598	7.472
6	11.75	.0855	.213	.324	.702	1.214	1.843	2.619	3.003
9	26.50	.0543	.1422	.2053	.4440	.7690	1.170	1.6650	2.4500
12	47.10	.040	.0983	.1480	.3206	.5500	.8437	1.1925	1.5925
15	73.50	.0295	.0754	.1170	.2430	.4240	.6500	.9190	1.2250
18	106	.0237	.0600	.0900	.1944	.3400	.5208	.7425	.9975
21	144	.0193	.0492	.0729	.1607	.2800	.4286	.6043	.8150
24	188	.0166	.0413	.0625	.1350	.2350	.3641	.5175	.6891
27	238	.0139	.0341	.0533	.1175	.2044	.3125	.4460	.5990
30	294	.0123	.0310	.0470	.1013	.1760	.2725	.3870	.5230
36	424	.0096	.0243	.0367	.0787	.1383	.2135	.3038	.4073
42	577	.0075	.0189	.0286	.0630	.1114	.1571	.2443	.3280
48	752	.0062	.0158	.0240	.0529	.0925	.1438	.2042	.2756
54	954	.0052	.0133	.0202	.0449	.0778	.1198	.1700	.2300
60	1176	.0044	.0113	.0173	.0383	.0667	.1062	.1458	.1972
66	1425	.0039	.0100	.0153	.0338	.0591	.0909	.1309	.1755
72	1696	.0035	.0089	.0137	.0301	.0530	.0815	.1162	.1698
78	1991	.0031	.0079	.0122	.0263	.0476	.0731	.1038	.1382
84	2308	.0028	.0072	.0110	.0243	.0426	.0656	.0939	.1256
90	2650	.0025	.0063	.0098	.0218	.0382	.0590	.0840	.1139
96	3008	.0022	.0055	.0088	.0196	.0342	.0531	.0754	.1018
102	3406	.0021	.0046	.0083	.0183	.0334	.0511	.0731	.1000
108	3816	.0019	.0043	.0075	.0172	.0307	.0482	.0693	.0964
120	4704	.0018	.0040	.0070	.0160	.0285	.0446	.0643	.0876
132	5702	.0017	.0038	.0067	.0154	.0276	.0430	.0619	.0851
144	6784	.0015	.0032	.0060	.0131	.0241	.0374	.0523	.0735

Velocity of Water

Table giving velocity of water in feet per second, and the cubic feet of water per minute, to develop one horse power at 80 per cent. duty under heads from 1 to 108 feet.

Head	Velocity	Cubic Feet	Head	Velocity	Cubic Feet	Head	Velocity	Cubic Feet
1	8.02	661.765	37	48.78	17.886	73	68.53	9.065
2	11.34	330.883	38	49.44	17.415	74	69.00	8.943
3	13.89	220.589	39	50.09	16.968	75	69.46	8.822
4	16.04	165.441	40	50.72	16.544	76	69.92	8.707
5	17.92	132.353	41	51.35	16.141	77	70.38	8.594
6	19.65	110.294	42	51.98	15.756	78	70.84	8.484
7	21.22	94.538	43	52.59	15.390	79	71.29	8.377
8	22.68	82.720	44	53.20	15.040	80	71.74	8.272
9	24.06	73.529	45	53.80	14.706	81	72.19	8.170
10	25.36	66.177	46	54.40	14.368	82	72.63	8.070
11	26.60	60.160	47	54.99	14.080	83	73.07	7.973
12	27.78	55.147	48	55.57	13.787	84	73.51	7.878
13	28.92	50.905	49	56.14	13.505	85	73.95	7.785
14	30.01	47.269	50	56.71	13.236	86	74.38	7.695
15	31.06	44.118	51	57.27	12.976	87	74.81	7.606
16	32.08	41.360	52	57.84	12.726	88	75.24	7.520
17	33.07	38.927	53	58.39	12.486	89	75.67	7.436
18	34.03	36.765	54	58.93	12.255	90	76.09	7.353
19	34.96	34.830	55	59.48	12.032	91	76.51	7.272
20	35.87	33.088	56	60.01	11.817	92	76.93	7.193
21	36.75	31.513	57	60.56	11.610	93	77.35	7.116
22	37.61	30.080	58	61.08	11.410	94	77.76	7.040
23	38.46	28.772	59	61.61	11.216	95	78.18	6.966
24	39.29	27.574	60	62.12	11.029	96	78.59	6.893
25	40.10	26.471	61	62.71	10.849	97	79.00	6.822
26	40.89	25.453	62	63.15	10.674	98	79.40	6.753
27	41.67	24.510	63	63.66	10.504	99	79.81	6.685
28	42.44	23.634	64	64.16	10.340	100	80.22	6.618
29	43.19	22.819	65	64.66	10.181	101	80.61	6.552
30	43.93	22.059	66	65.16	10.027	102	81.01	6.487
31	44.65	21.347	67	65.65	9.877	103	81.40	6.425
32	45.37	20.680	68	66.14	9.732	104	81.80	6.363
33	46.07	20.053	69	66.62	9.591	105	82.19	6.303
34	46.77	19.464	70	67.11	9.454	106	82.58	6.243
35	47.45	18.908	71	67.58	9.321	107	82.97	6.185
36	48.12	18.382	72	68.06	9.191	108	83.35	6.127

Quick Reference Facts

A cubic foot of water weighs 62.33 pounds, and contains 7.48 gallons. A cubic foot of soft wood, green, weighs 53 pounds; air dried, 30 pounds; kiln dried, 28 pounds. A cubic foot of hard wood, green, weighs 62 pounds; air dried, 46 pounds; kiln dried, 40 pounds. A cubic foot of cast iron weighs 450 pounds; wrought iron, 480 pounds; sandstone, 140 pounds; granite, 180 pounds; brickwork, 95 pounds. A ton of shipping is 42 cubic feet; a perch of stone is 22 cubic feet measured in wall, and 24.75 cubic feet measured in pile.

The mean pressure of the atmosphere is usually estimated at 14.7 pounds per square inch, so with a perfect vacuum it will sustain a column of mercury 29.9 inches, or a column of water 33.9 feet high.

Diameter of Circle	x 3.1416	equals	Circumference.
Circumference	x .31831	"	Diameter.
Diameter	x .8862	"	The side of an equal Square.
Diameter	x .8862	"	The side of an equal Square.
Side of a Square	x 1.128	"	Diameter of an equal Circle
Square of a Diameter	x .7854	"	The area of a Circle.
Square Root of Area	x 1.12837	"	Diameter of equal Circle.
Square of the Diameter of a Sphere	x 3 1416	"	Convex surface.
Cube of the Diameter of a Sphere	x .5236	"	Solidity.
Diameter of a Sphere	x .806	"	Dimensions of equal Cube.
Diameter of a Sphere	x .6667	"	Length of equal Cylinder.
Square inches	x .00695	"	Square feet.
Cubic inches	x .00058	"	Cubic feet.
Cubic feet	x .03704	"	Cubic yards.
Cylindrical inches	x .0004546	"	Cubic feet.
Cylindrical feet	x .02909	"	Cubic yards.
Cubic inches	x .003607	"	Imperial gallons.
Cubic feet	x .6232	"	" "
Cylindrical inches	x .002832	"	" "
Cylindrical feet	x 4.895	"	" "
183.346 Circular inches		"	1 Square foot.
2200 Cylindrical inches		"	1 Cubic foot.
7.4805 U. S. Gallons		"	1 Cubic foot.
Square root the Head	x 8.02	"	Spouting velocity per sec.
Diameter of Circle	x .7071	"	Side of an inscribed Square
Avoirdupois pounds	x .009	"	Cwts.
Avoirdupois pounds	x .00045	"	Tons.
Lineal feet	x .00019	"	Statute miles.
Lineal yards	x .000568	"	Statute miles.

American, or Brown and Sharpe (B. & S.), Wire Gage for Measuring the Diameter of Electrical Wiring.

B. & S. Gauge Number	Diameter of Solid Wire in Mils	Area in Circular Mils	Table A Rubber Insulation Amperes	Table B other Insulation Amperes
18	40.3	1,624	3	5
16	50.8	2,583	6	10
14	64.1	4,107	15	20
12	80.8	6,530	20	25
10	101.9	10,380	25	30
8	128.5	16,510	35	50
6	162.0	26,250	50	70
5	181.9	33,100	55	80
4	204.3	41,740	70	90
3	229.4	52,630	80	100
2	257.6	66,370	90	125
1	289.3	83,690	100	150
0	325.	105,500	125	200
00	364.8	133,100	150	225
000	409.6	167,800	175	275
		200,000	200	300
0000	460.	211,600	225	325
		300,000	275	400
		400,000	325	500
		500,000	400	600
		600,000	450	680
		700,000	500	760
		800,000	550	840
		900,000	600	920
		1,000,000	650	1,000
		1,100,000	690	1,080
		1,200,000	730	1,150
		1,300,000	770	1,220
		1,400,000	810	1,290
		1,500,000	850	1,360
		1,600,000	890	1,430
		1,700,000	930	1,490
		1,800,000	970	1,550
		1,900,000	1,010	1,610
		2,000,000	1,050	1,670

1 Mil = 0.001 inch.

LUMBER MEASURE IN BOARD FEET

LENGTH Size in inches	12 ft.	14 ft.	16 ft.	18 ft.	20 ft.	22 ft.	24 ft.	26 ft.	28 ft.	30 ft.	32 ft.	34 ft.	36 ft.	38 ft.	40 ft.
1 x 4	4	4½	5½	6	6½	7½	8	8½	9½	10	11	11½	12	12½	13
1 x 6	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1 x 8	8	9⅓	10⅔	12	13⅓	14⅔	16	17⅓	18⅔	20	21⅓	22⅔	24	25⅓	26⅔
1 x 10	10	11⅔	13⅔	15	16⅔	18⅓	20	21⅔	23⅓	25	26⅔	28⅓	30	31⅔	33⅓
1 x 12	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40
1 x 14	14	16⅓	18⅔	21	23⅓	25⅔	28	30⅓	32⅔	35	37⅓	39⅔	42	44⅓	46⅔
1 x 16	16	18⅔	21⅓	24	26⅔	29⅓	32	34⅔	37⅓	40	42⅔	45⅓	48	50⅔	53⅓
2 x 3	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
2 x 4	8	9⅓	10⅔	12	13⅓	14⅔	16	17⅓	18⅔	20	21⅓	22⅔	24	25⅓	26⅔
2 x 6	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40
2 x 8	16	18⅔	21⅓	24	26⅔	29⅓	32	34⅔	37⅓	40	42⅔	45⅓	48	50⅔	53⅓
2 x 10	20	23⅓	26⅔	30	33⅓	36⅔	40	43⅓	46⅔	50	53⅓	56⅔	60	63⅓	66⅔
2 x 12	24	28	32.	36	40	44	48	52	56	60	64	68	72	76	80
2 x 14	28	32⅔	37⅓	42	46⅔	51⅓	56	60⅔	65⅓	70	72⅔	79⅓	84	88⅔	93⅓
2 x 16	32	37⅓	42⅔	48	53⅓	58⅔	64	69⅓	74⅔	80	85⅓	90⅔	96	101⅓	106⅔
3 x 4	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40
3 x 6	18	21	24	27	30	33	36	39	42	45	48	51	54	57	60
3 x 8	24	28	32	36	40	44	48	52	56	60	64	68	72	76	80
3 x 10	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100
3 x 12	36	42	48	54	60	66	72	78	84	90	96	102	108	114	120
3 x 14	42	49	56	63	70	77	84	91	98	105	112	119	126	133	140
3 x 16	48	56	64	72	80	88	96	104	112	120	128	136	144	152	160
4 x 4	16	18⅔	21⅓	24	26⅔	29⅓	32	34⅔	37⅓	40	42⅔	45⅓	48	50⅔	53⅓
4 x 6	24	28	32	36	40	44	48	52	56	60	64	68	72	76	80
4 x 8	32	37⅓	42⅔	48	53⅓	58⅔	64	69⅓	74⅔	80	85⅓	90⅔	96	101⅓	106⅔
4 x 10	40	46⅔	53⅓	60	66⅔	73⅓	80	86⅔	93⅓	100	106⅔	113⅓	120	126⅔	133⅓
4 x 12	48	56	64	72	80	88	96	104	112	120	128	136	144	152	160
4 x 14	56	65⅓	74⅔	84	93⅓	102⅔	112	121⅓	130⅔	140	149⅓	158⅔	168	177⅓	186⅔
4 x 16	64	74⅔	85⅓	96	106⅔	117⅓	128	138⅔	149⅓	160	170⅔	181⅓	192	202⅔	213⅓

LUMBER MEASURE IN BOARD FEET (Continued)

LENGTH / Size in inches	12 ft.	14 ft.	16 ft.	18 ft.	20 ft.	22 ft.	24 ft.	26 ft.	28 ft.	30 ft.	32 ft.	34 ft.	36 ft.	38 ft.	40 ft.
6 x 6	36	42	48	54	60	66	72	78	84	90	96	102	108	114	120
6 x 8	48	56	64	72	80	88	96	104	112	120	128	136	144	152	160
6 x 10	60	70	80	90	100	110	120	130	140	150	160	170	180	190	200
6 x 12	72	84	96	108	120	132	144	156	168	180	192	204	216	228	240
6 x 14	84	98	112	126	140	154	168	182	196	210	224	238	252	266	280
6 x 16	96	112	128	144	160	176	192	208	224	240	256	272	288	304	320
8 x 8	64	74⅔	85⅓	96	106⅔	117⅓	128	138⅔	149⅓	160	170⅔	181⅓	192	202⅔	213⅓
8 x 10	90	93⅓	106⅔	120	133⅓	146⅔	160	173⅓	186⅔	200	213⅓	226⅔	240	253⅓	266⅔
8 x 12	96	112	128	144	160	176	192	208	224	240	256	272	288	304	320
8 x 14	112	130⅔	149⅓	168	186⅔	205⅓	224	242⅔	261⅓	280	298⅔	317⅓	336	354⅔	373⅓
8 x 16	128	149⅓	170⅔	192	213⅓	234⅔	256	277⅓	298⅔	320	341⅓	362⅔	384	405⅓	426⅔
10 x 10	100	116⅔	133⅓	150	166⅔	183⅓	200	216⅔	233⅓	250	266⅔	283⅓	300	316⅔	333⅓
10 x 12	120	140	160	180	200	220	240	260	280	300	320	340	360	380	400
10 x 14	140	163⅓	186⅔	210	233⅓	256⅔	280	303⅓	326⅔	350	373⅓	396⅔	410	443⅓	466⅔
10 x 16	160	186⅔	213⅓	240	266⅔	293⅓	320	346⅔	373⅓	400	426⅔	453⅓	480	506⅔	533⅓
12 x 12	144	168	192	216	240	264	288	312	336	360	384	408	432	456	480
12 x 14	168	196	224	252	280	308	336	364	392	420	448	476	504	532	560
12 x 16	192	224	256	288	320	352	384	416	448	480	512	544	576	608	640
14 x 14	196	228⅔	261⅓	294	326⅔	359⅓	392	424⅔	457⅔	490	522⅔	555⅓	588	620⅔	653⅓
14 x 16	224	261⅓	298⅔	336	373⅓	410⅔	448	485⅓	522⅓	560	597⅓	634⅔	672	709⅓	746⅔
16 x 16	256	298⅔	341⅓	384	426⅔	469⅓	512	554⅔	597⅓	640	682⅔	725⅓	768	810⅔	853⅓

Rule for Finding the Length of Belts

Add the diameter of the two pulleys together, multiply by 3 1-7, divide the product by 2, add to the quotient twice the distance between the centers of the shafts, and the sum will be the required length.

The power a belt is able to transmit depends upon the diameter of the pulley and the arc of contact.

It increases with the diameter and arc of contact.

If arc of contact is only one-third of circumference, the power of the belt if 30 per cent less; and if arc of contact is two-thirds of circumference the power is 25 per cent more than of that given in the table.

A belt will not transmit more power spliced than laced, unless used with a tightener; then splicing is preferable.

With a tightener, however, and the belt being spliced, it transmits 10 per cent to 15 per cent more than that given in the table for any given width of belt.

Always figure the power of the belt by the smaller of the two pulleys over which it runs.

The table given on the succeeding pages covering double belting is computed with the assumption that the pulley is five feet in diameter and the arc of contact one-half the circumference.

The table given on the succeeding pages covering single belting is computed assuming that the pulley is three feet in diameter and the arc of contact one-half of circumference.

Rubber belts should be used 20 per cent to 25 per cent wider than leather belts to transmit the same power.

Comparison of Rubber and Leather Belting

In the following, Rubber Belting made from 32-ounce Cotton Duck has been taken as a basis for comparison:

2 Ply Rubber Belt=Light Single Leather Belt.
3 Ply Rubber Belt=Medium Single Leather Belt.
4 Ply Rubber Belt=Heavy Single Leather Belt.
5 Ply Rubber Belt—Light Double Leather Belt.
6 Ply Rubber Belt=Medium Double Leather Belt.
7 Ply Rubber Belt=Heavy Double Leather Belt.
8 Ply Rubber Belt= Triple Leather Belt.

Horse Power Transmitted by Single Leather Belts

Belts supposed not to be overstrained, so they will last.

1 inch wide, 800 feet per minute = 1 Horse power.

Speed in Feet per Minute	WIDTH OF BELTS IN INCHES											
	2	3	4	5	6	8	10	12	14	16	18	20
	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.
400	1	1½	2	2½	3	4	5	6	7	8	9	10
600	1½	2¼	3	3¾	4½	6	7½	9	10½	12	13½	15
800	2	3	4	5	6	8	10	12	14	16	18	20
1000	2½	3¾	5	6¼	7½	10	12½	15	17½	20	22½	25
1200	3	4½	6	7½	9	12	15	18	21	24	27	30
1500	3¾	5¾	7½	9½	11½	15	18¾	22½	26½	30	33¾	37½
1800	4½	6¾	9	11¼	13½	18	22½	27	31½	36	40½	45
2000	5	7½	10	12½	15	20	25	30	35	40	45	50
2400	6	9	12	15	18	24	30	36	42	48	54	60
2800	7	10½	14	17½	21	28	35	42	49	56	63	70
3000	7½	11¼	15	18¾	22½	30	37½	45	52½	60	67½	75
3500	8¾	13	17½	22	26	35	44	52½	61	70	79	88
4000	10	15	20	25	30	40	50	60	70	80	90	100
4500	11¼	17	22½	28	34	45	57	69	78	90	102	114
5000	12½	19	25	31	37½	50	62½	75	87½	100	112	125

Horse Power Transmitted by Double Leather Belts

Belts supposed not to be overstrained, so they will last.

1 inch wide, 550 feet per minute = 1 Horse Power.

Speed in Feet per Minute	WIDTH OF BELTS IN INCHES												
	4	6	8	10	12	14	16	18	20	22	24	28	
	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	H
400	$2\frac{3}{4}$	$4\frac{1}{4}$	$5\frac{3}{4}$	$7\frac{1}{4}$	$8\frac{1}{2}$	10	$11\frac{1}{2}$	13	$14\frac{1}{2}$	16	$17\frac{1}{2}$	20	
600	$4\frac{1}{4}$	$6\frac{1}{2}$	$8\frac{3}{4}$	11	13	15	$17\frac{1}{2}$	$19\frac{1}{2}$	22	24	26	$30\frac{1}{2}$	
800	$5\frac{3}{4}$	$8\frac{1}{2}$	$11\frac{1}{2}$	$14\frac{1}{2}$	$17\frac{1}{2}$	$20\frac{1}{2}$	23	26	29	32	$34\frac{1}{2}$	$40\frac{1}{2}$	
1000	$7\frac{1}{4}$	11	$14\frac{1}{2}$	$18\frac{1}{4}$	$21\frac{1}{2}$	$25\frac{1}{2}$	29	$32\frac{1}{2}$	36	40	$43\frac{1}{2}$	51	
1200	$8\frac{1}{2}$	13	$17\frac{1}{2}$	22	26	$30\frac{1}{2}$	$34\frac{1}{2}$	39	44	48	$52\frac{1}{2}$	$60\frac{1}{2}$	
1500	$10\frac{3}{4}$	$16\frac{1}{4}$	$21\frac{3}{4}$	$27\frac{1}{4}$	$32\frac{1}{2}$	38	$43\frac{1}{2}$	49	$54\frac{1}{2}$	60	$65\frac{1}{2}$	$76\frac{1}{2}$	
1800	13	$19\frac{1}{2}$	26	$32\frac{3}{4}$	39	$45\frac{1}{2}$	52	59	$65\frac{1}{2}$	72	$78\frac{1}{2}$	$91\frac{1}{2}$	
2000	$14\frac{1}{2}$	$21\frac{3}{4}$	29	$36\frac{1}{2}$	$43\frac{1}{2}$	$50\frac{1}{2}$	58	$65\frac{1}{2}$	$72\frac{1}{2}$	80	87	102	1
2400	$17\frac{1}{4}$	26	$34\frac{3}{4}$	44	$52\frac{1}{2}$	$60\frac{1}{2}$	$69\frac{1}{2}$	$78\frac{1}{2}$	88	96	105	122	1
2800	$20\frac{1}{4}$	$30\frac{1}{2}$	$40\frac{1}{2}$	51	61	71	81	$91\frac{1}{2}$	102	112	122	142	1
3000	$21\frac{1}{2}$	$32\frac{1}{2}$	$43\frac{1}{2}$	$54\frac{1}{2}$	$65\frac{1}{2}$	76	$87\frac{1}{2}$	98	108	120	131	153	1
3500	$25\frac{1}{2}$	38	$50\frac{3}{4}$	$63\frac{1}{2}$	76	89	101	114	127	140	153	178	1
4000	29	$43\frac{1}{2}$	$58\frac{1}{4}$	$72\frac{3}{4}$	87	101	116	131	145	160	174	204	2
4500	$32\frac{1}{2}$	49	65	82	98	114	131	147	163	180	196	229	2
5000	$36\frac{1}{2}$	$54\frac{1}{2}$	$72\frac{3}{4}$	91	109	127	145	163	182	200	218	254	2

Miscellaneous Weights

	Average Weight Cubic Ft.	Average Weight Cubic In.
Cast Iron, -	450 pounds	.260 pounds
Wrought Iron,	485 "	.281 "
Gun Metal,	528 "	.306 "
White Pine,	25 "	.015 "
Steel,	489 "	.283 "

Shrinkage of Castings

Cast Iron, -	1/8 inch per lineal foot
Brass,	3/16 inch per lineal foot
Tin,	1/2 inch per lineal foot
Zinc,	5/16 inch per lineal foot

Melting Point of Metals, Etc.

Names.	Fahr.	Names.	Fahr.
Platina,	4590	Wrought Iron,	2900
Antimony,	842	Steel,	2500
Bismuth,	487	Copper,	2000
Tin,	475	Glass,	2377
Lead,	620	Beeswax,	151
Zinc,	700	Sulphur,	239
Cast Iron,	2100	Tallow,	92

Areas and Circumferences of Circles

Dia. in inch	Circ'm in ft.	in.	Area in Square Inches	Dia. in ft.	in.	Circ'm in ft.	in.	Area in Square Feet	Dia. in ft.	in.	Circ'm in ft.	in.	Area in Square Feet
1		3⅛	.7854	1	2	3	7⅞	1.0775	3	2	9	11⅜	7.8681
1¼		3⅞	1.227	1	2½	3	9½	1.1569	3	2½	10	0⅞	8.0846
1½		4⅝	1.767	1	3	3	11⅛	1.2370	3	3	10	2½	8.2951
1¾		5½	2.405	1	3½	4	0⅝	1.3208	3	3½	10	4	8.5091
2		6¼	3.141	1	4	4	2¼	1.4074	3	4	10	5⅝	8.7269
2¼		7	3.976	1	4½	4	3¾	1.4967	3	4½	10	7¼	8.9462
2½		7¾	4.908	1	5	4	5⅜	1.5888	3	5	10	8¾	9.1686
2¾		8⅝	5.939	1	5½	4	6⅞	1.6836	3	5½	10	10⅜	9.3936
3		9⅜	7.068	1	6	4	8½	1.7812	3	6	10	11⅞	9.6212
3¼		10¼	8.295	1	6½	4	10⅛	1.8816	3	6½	11	1½	9.8518
3½		11	9.621	1	7	4	11⅝	1.9847	3	7	11	3	10.084
3¾		11¾	11.044	1	7½	5	1¼	2.0904	3	7½	11	4⅝	10.320
4	1	0½	12.566	1	8	5	2⅞	2.1990	3	8	11	6¼	10.559
4¼	1	1⅜	14.186	1	8½	5	4⅜	2.3103	3	8½	11	7¾	10.800
4½	1	2⅛	15.904	1	9	5	5⅞	2.4244	3	9	11	9⅜	11.044
4¾	1	2⅞	17.720	1	9½	5	7½	2.5412	3	9½	11	10⅞	11.291
5	1	3⅝	19.635	1	10	5	9⅛	2.6608	3	10	12	0½	11.534
5¼	1	4½	21.647	1	10½	5	10⅝	2.7632	3	10½	12	2	11.793
5½	1	5¼	23.758	1	11	6	0¼	2.8903	3	11	12	3⅝	12.048
5¾	1	6	25.967	1	11½	6	1¾	3.0129	3	11½	12	5¼	12.305
6	1	6¾	28.274	2	0	6	3⅜	3.1418	4	0	12	6¾	12.566
6¼	1	7⅝	30:679	2	0½	6	4⅞	3.2731	4	0½	12	8⅜	12.829
6½	1	8⅜	33.183	2	1	6	6½	3.4081	4	1	12	9⅞	13.095
6¾	1	9⅛	35.784	2	1½	6	8⅛	3.5468	4	1½	12	11½	13.364
7	1	10	38.484	2	2	6	9⅝	3.6870	4	2	13	1	13.635
7¼	1	10¾	41.282	2	2½	6	11¼	3.8302	4	2½	13	2⅝	13.909
7½	1	11½	44.178	2	3	7	0¾	3.9761	4	3	13	4¼	14.186
7¾	2	0⅜	47.173	2	3½	7	2⅜	4.1241	4	3½	13	5¾	14.465
8	2	1⅛	50.265	2	4	7	3⅞	4.2760	4	4	13	7⅜	14.748
8¼	2	1⅞	53.456	2	4½	7	5½	4.4302	4	4½	13	8⅞	15.033
8½	2	2⅝	56.745	2	5	7	7	4.5861	4	5	13	10½	15.320
8¾	2	3⅜	60.132	2	5½	7	8⅝	4.7467	4	5½	14	0	15.611
9	2	4¼	63.617	2	6	7	10¼	4.9081	4	6	14	1⅝	15.904
9¼	2	5	67.200	2	6½	7	11¾	5.0731	4	6½	14	3¼	16.200
9½	2	5¾	70.882	2	7	8	1⅜	5.2278	4	7	14	4¾	16.498
9¾	2	6⅝	74.662	2	7½	8	2⅞	5.4112	4	7½	14	6⅜	16.800
10	2	7⅜	78.540	2	8	8	4½	5.5850	4	8	14	7⅞	17.104
10¼	2	8⅛	82.516	2	8½	8	6⅛	5.7601	4	8½	14	9½	17.411
10½	2	8⅞	86.590	2	9	8	7⅝	5.9398	4	9	14	11	17.720
10¾	2	9¾	90.762	2	9½	8	9¼	6.1201	4	9½	15	0⅝	18.033
11	2	10½	95.789	2	10	8	10¾	6.3051	4	10	15	2¼	18.347
11¼	2	11¼	100.195	2	10½	9	0⅜	6.4911	4	10½	15	3¾	18.665
11½	3	0⅛	104.688	2	11	9	1⅞	6.6815	4	11	15	5¼	18.985
11¾	3	0⅞	109.296	2	11½	9	3½	6.8738	4	11½	15	6⅞	19.309
12	3	1⅝	113.990	3	0	9	5	7.0688	5	0	15	8½	19.635
12½	3	3¼	123.696	3	0½	9	6⅝	7.2664	5	0½	15	10	19.963
13	3	4¾	133.790	3	1	9	8¼	7.4661	5	1	15	11⅝	20.294
13½	3	6⅜	144.223	3	1½	9	9⅞	7.6691	5	1½	16	1¼	20.629

Areas and Circumferences of Circles

Dia. in ft.	Dia. in in.	Circ'm in ft.	Circ'm in in.	Area in Square Feet	Dia. in ft.	Dia. in in.	Circ'm in ft.	Circ'm in in.	Area in Square Feet	Dia. in ft.	Dia. in in.	Circ'm in ft.	Circ'm in in.	Area in Square Feet
5	2	16	2¾	20.965	7	4	23	0⅜	42.2367	11	4	35	7¼	100.8797
5	2½	16	4¼	21.305		5	23	2⅛	43.2028		5	35	10⅝	102.3689
5	3	16	5⅞	21.647		6	23	6¾	44.1787		6	36	1½	103.8691
5	3½	16	7½	21.992		7	23	11	45.1656		7	36	4½	105.3794
5	4	16	9	22.333		8	24	1⅛	46.1638		8	36	7⅞	106.9013
5	4½	16	10⅝	22.621		9	24	4⅛	47.1730		9	36	10⅞	108.4342
5	5	17	0⅛	23.043		10	24	7¼	48.1926		10	37	2¾	109.9772
5	5½	17	1¾	23.330		11	24	10⅜	49.2236		11	37	5¼	111.5319
5	6	17	3⅔	23.758	8	0	25	1½	50.2656	12	0	37	8⅜	113.0976
5	6½	17	4⅞	24.119		1	25	4⅝	51.3178		1	37	11½	114.6732
5	7	17	6½	24.483		2	25	7⅞	52.3816		2	38	2⅝	116.2607
5	7½	17	8	24.850		3	25	11	53.4562		3	38	5¾	117.8590
5	8	17	9⅝	25.220		4	26	2⅛	54.5412		4	38	8⅞	119.4674
5	8½	17	11⅛	25.592		5	26	5¼	55.6377		5	39	0	121.0876
5	9	18	0¾	25.964		6	26	8⅜	56.7451		6	39	3¼	122.7187
5	9½	18	2¼	26.344		7	26	11½	57.8628		7	39	6⅜	124.3598
5	10	18	3⅞	26.725		8	27	2¾	58.9920		8	39	9½	126.0127
5	10½	18	5½	27.108		9	27	5¾	60.1321		9	40	0⅝	127.6765
5	11	18	7	27.494		10	27	9	61.2826		10	40	3¾	129.3504
5	11½	18	8⅝	27.883		11	28	0⅛	62.4445		11	40	6⅞	131.0360
6	0	18	10⅛	28.274	9	0	28	3¼	63.6174	13	0	40	10	132.7326
6	0½	18	11¾	28.663		1	28	6⅜	64.8006		1	41	1⅛	134.4391
6	1	19	1¼	29.065		2	28	9½	65.9951		2	41	4⅜	136.1574
6	1½	19	2⅞	29.466		3	29	0⅝	67.2007		3	41	7½	137.8867
6	2	19	4½	29.867		4	29	3¾	68.4166		4	41	10⅝	139.6260
6	2½	19	6	30.271		5	29	7	69.6440		5	42	1⅝	141.3771
6	3	19	7⅝	30.679		6	29	10⅛	70.8823		6	42	4⅞	143.1391
6	3½	19	9⅛	31.090		7	30	1¼	72.1309		7	42	8	144.9111
6	4	19	10¾	31.503		8	30	4⅜	73.3910		8	42	11⅛	146.6949
6	4½	20	0¼	31.919		9	30	7½	74.6620		9	43	2¼	148.4896
6	5	20	1⅞	32.337		10	30	11⅝	75.9433		10	43	5½	150.2943
6	5½	20	3½	32.759		11	31	1¾	77.2362		11	43	8⅝	152.1109
6	6	20	5	33.183	10	0	31	5	78.5400	14	0	43	11¾	153.9384
6	6½	20	6½	33.619		1	31	8⅛	79.8540		1	44	2⅞	155.7758
6	7	20	8⅛	34.039		2	31	11¼	81.1795		2	44	6	157.6250
6	7½	20	9¾	34.471		3	32	2⅜	82.5160		3	44	9⅛	159.4852
6	8	20	11¼	34.906		4	32	5½	83.8627		4	45	0¼	161.3553
6	8½	21	0⅞	35.344		5	32	8⅝	85.2000		5	45	3½	163.2373
6	9	21	2⅜	35.784		6	32	11¾	86.5880		6	45	6⅝	165.1303
6	9½	21	4	36.227		7	33	2⅞	87.9697		7	45	9¾	167.0331
6	10	21	5½	36.674		8	33	6⅛	89.3608		8	46	0⅞	168.9479
6	10½	21	7⅛	37.122		9	33	9¼	90.7627		9	46	4	170.8735
6	11	21	8¾	37.573		10	34	0⅜	92.1749		10	46	7⅛	172.8091
6	11½	21	10¼	38.027		11	34	3½	93.5986		11	46	11¼	174.7565
7	0	21	11⅞	38.4846	11	0	34	6⅝	95.0334	15	0	47	1½	176.7150
7	1	22	3	39.4060		1	34	9¾	96.4783		1	47	4⅝	178.6832
7	2	22	6⅛	40.3388		2	35	0⅞	97.9347		2	47	7¾	180.6634
7	3	22	9¼	41.2825		3	35	4⅛	99.4021		3	47	10⅞	182.6545

Fractions of Lineal Inch in Decimals

Lineal Inches	Lineal Foot	Lineal Inches	Lineal Foot	Lineal Inches	Lineal Foot
$\frac{1}{64}$	0.001302083	$1\frac{7}{8}$	0.15625	$6\frac{3}{4}$	0.5625
$\frac{1}{32}$	0.00260416	2	0.1666	7	0.5833
$\frac{1}{16}$	0.0052083	$2\frac{1}{8}$	0.177083	$7\frac{1}{4}$	0.60416
$\frac{1}{8}$	0.010416	$2\frac{1}{4}$	0.1875	$7\frac{1}{2}$	0.625
$\frac{3}{16}$	0.015625	$2\frac{3}{8}$	0.197916	$7\frac{3}{4}$	0.64583
$\frac{1}{4}$	0.02083	$2\frac{1}{2}$	0.2083	8	0.66667
$\frac{5}{16}$	0.0260416	$2\frac{5}{8}$	0.21875	$8\frac{1}{4}$	0.6875
$\frac{3}{8}$	0.03125	$2\frac{3}{4}$	0.22916	$8\frac{1}{2}$	0.7083
$\frac{7}{16}$	0.0364583	$2\frac{7}{8}$	0.239583	$8\frac{3}{4}$	0.72916
$\frac{1}{2}$	0.0416	3	0.25	9	0.75
$\frac{9}{16}$	0.046875	$3\frac{1}{4}$	0.27083	$9\frac{1}{4}$	0.77083
$\frac{5}{8}$	0.052083	$3\frac{1}{2}$	0.2916	$9\frac{1}{2}$	0.7916
$\frac{11}{16}$	0.0572916	$3\frac{3}{4}$	0.3125	$9\frac{3}{4}$	0.8125
$\frac{3}{4}$	0.0625	4	0.33333	10	0.83333
$\frac{13}{16}$	0.0677083	$4\frac{1}{4}$	0.35416	$10\frac{1}{4}$	0.85416
$\frac{7}{8}$	0.072916	$4\frac{1}{2}$	0.375	$10\frac{1}{2}$	0.875
$\frac{15}{16}$	0.078125	$4\frac{3}{4}$	0.39583	$10\frac{3}{4}$	0.89583
1	0.0833	5	0.4166	11	0.9166
$1\frac{1}{8}$	0.09375	$5\frac{1}{4}$	0.4375	$11\frac{1}{4}$	0.9375
$1\frac{1}{4}$	0.10416	$5\frac{1}{2}$	0.4583	$11\frac{1}{2}$	0.9583
$1\frac{3}{8}$	0.114583	$5\frac{3}{4}$	0.47916	$11\frac{3}{4}$	0.97916
$1\frac{1}{2}$	0.125	6	0.5	12	1.000
$1\frac{5}{8}$	0.135416	$6\frac{1}{4}$	0.52083		
$1\frac{3}{4}$	0.14583	$6\frac{1}{2}$	0.5416		

Lineal Inches in Decimal Fractions of a Lineal Foot

Fractions	Decimals of an inch	Fractions	Decimals of an inch	Fractions	Decimals of an inch	Fractions	Decimals of an inch
$\frac{1}{64}$	0.015625	$\frac{17}{64}$	0.265625	$\frac{33}{64}$	0.515635	$\frac{49}{64}$	0.765625
$\frac{1}{32}$	0.03125	$\frac{9}{32}$	0.28125	$\frac{17}{32}$	0.53125	$\frac{25}{32}$	0.78125
$\frac{3}{64}$	0.04687	$\frac{19}{64}$	0.296875	$\frac{35}{64}$	0.546875	$\frac{51}{64}$	0.796875
$\frac{1}{16}$	0.0625	$\frac{5}{16}$	0.3125	$\frac{9}{16}$	0.5625	$\frac{13}{16}$	0.8125
$\frac{5}{64}$	0.078125	$\frac{21}{64}$	0.328125	$\frac{37}{64}$	0.578125	$\frac{53}{64}$	0.828125
$\frac{3}{32}$	0.09375	$\frac{11}{32}$	0.34375	$\frac{19}{32}$	0.59375	$\frac{27}{32}$	0.84375
$\frac{7}{64}$	0.109375	$\frac{23}{64}$	0.359375	$\frac{39}{64}$	.609375	$\frac{55}{64}$	0.859375
$\frac{1}{8}$	0.125	$\frac{3}{8}$	0.375	$\frac{5}{8}$	0.625	$\frac{7}{8}$	0.875
$\frac{9}{64}$	0.140625	$\frac{25}{64}$	0.390625	$\frac{41}{64}$	0.640625	$\frac{57}{64}$	0.890625
$\frac{5}{32}$	0.15625	$\frac{13}{32}$	0.40625	$\frac{21}{32}$	0.65625	$\frac{29}{32}$	0.90625
$\frac{11}{64}$	0.171875	$\frac{27}{64}$	0.421875	$\frac{43}{64}$	0.671875	$\frac{59}{64}$	0.921875
$\frac{3}{16}$	0.1875	$\frac{7}{16}$	0.4375	$\frac{11}{16}$	0.6875	$\frac{15}{16}$	0.9375
$\frac{13}{64}$	0.203125	$\frac{29}{64}$	0.453125	$\frac{45}{64}$	0.703125	$\frac{61}{64}$	0.953125
$\frac{7}{32}$	0.21875	$\frac{15}{32}$	0.46875	$\frac{23}{32}$	0.71875	$\frac{31}{32}$	0.96875
$\frac{15}{64}$	0.234375	$\frac{31}{64}$	0.484375	$\frac{47}{64}$	0.734375	$\frac{63}{64}$	0.984375
$\frac{1}{4}$	0.25	$\frac{1}{2}$	0.5	$\frac{3}{4}$	0.75	1	1.000

Fifty Years of Free Service in Water Power Development

It is sound business sense for any country or town dweller near a small stream to take thought of the stream's possibilities, the opportunity it has in it for the bettering of his home or his town. Since it will cost him nothing to obtain such valuable information it is doubly sound business sense. Almost a half century (since 1872) the Rodney Hunt Machine Company, Orange, Massachusetts, U. S. A., has maintained that the good will it must have to succeed must be built on the thorough willingness of its staff to give accurate, complete, dependable, and friendly help to those who need advice on machinery for water power development and for various forms of water usages. This information is available to anyone at any time simply for the asking. No matter whether the person obtaining any service that we can give buys from us or elsewhere, this friendly and reliable service is always open to him. This policy has proved its worth in nearly a half century of painstaking practice and has developed a surprising business, that has been built on good will and sincerity. "We will just as quickly tell you not to install a water power plant, if you have not the proper location for a plant, as we would tell you to buy a plant, if you are situated where a water power plant would make good." Any questions on water possibilities or problems will be answered promptly, fully, and gladly. The following are suggestions for questions to ask in investigating water power possibilities:

1. Are you situated in a level valley, in mountainous or hilly country and has the stream many falls, rapids or riffles where dams might be located?

2. What is the source of the stream's flow, springs, snow in the mountains?

3. What is the approximate flow of the stream in cubic feet, as determined by the weir or chip method?

4. How much fall or head has the stream, as determined by the dry-foot method?

5. Does the stream freeze in winter; if so, how is the volume of water affected—is it greatly decreased?

6. Does the stream dry up in summer; if so how long does it flow?

7. About how many acres could be used conveniently for a pond to store water?

8. Have you now a pond or dam—please give size and average depth and head of water?

9. Is your stream subject to floods?

10. Does your stream pass a lumber camp?

11. What kind of machinery do you wish to operate?

12. Have you a water wheel; if so, please mention size, amount of power developed, volume of water the wheel is using and if it seems to be developing the right amount of power for the volume and head of water used? Have you a trash rack, flume, penstock or any other similar apparatus?